A Trace Element Emission Study at Selected Sour Gas Plant Incinerator Stacks in The Province of Alberta

Strachan - Gulf Oil Canada Limited
Ram River - Canterra Energy Limited
Jumping Pound - Shell Canada Limited

for

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SUMMARY

A comprehensive source sampling program has been carried out at the Gulf Oil Canada Limited - Strachan, Canterra Energy Limited - Ram River and Shell Canada Limited - Jumping Pound Gas Plants to establish the presence and levels of 29 metals in the gases exhausted from incinerator stacks. Modifications to the Alberta Stack Sampling Code procedures were made in order to facilitate representative sample collection, quantitative recovery and elemental analyses in the presence of other particulate matter. Average concentrations and emission rates of the metals found most frequently at each plant with glass lined probes are as follows:

(Arithmetic Means with Standard Deviations)

Metal	Strachan Volumetric Flowrate 230,000 acfm		Ram River Volumetric Flowrate 1,000,000 acfm		Jumping Pound Volumetric Flowrate 223,00 acfm	
	Average Concentration ug/rcf	Average Emission Rate g/h	Average Concentration ug/rcf	Average Emission Rate g/h	Average Concentration ug/rcf	Average Emission Rate g/h
Aluminum	54±21	240±85	125±35	2400±560	11±6	40±20
Arsenic	0.05±0.01	0.21±0.02	—	—	—	—
Cadmium	0.16±0.08	0.69±0.32	0.18±0.04	3.4±0.6	3.5±5.7	13±22
Chromium	1.5±0	6.6±0.1	—	—	2.3±1.4	9.0±5.2
Copper	3.3±3.8	14±17	—	—	1.7±0.7	6.5±2.6
Iron	8.7±3.3	39±15	6.3±1.1	120±14	27±28	102±100
Lithium	0.16±0.04	0.69±0.15	0.17±0.01	3.2±0.1	—	—
Manganese	—	—	—	—	1.3±0.7	4.9±2.6
Nickel	1.5±0	6.6±0.1	—	—	4.6±4.5	18±17
Lead	2.3±0.1	9.9±0.1	—	—	11±15	37±54
Strontium	—	—	1.0±0.4	19±7	0.51±0.18	2.0±0.7
Titanium	13±3	59±9	15±2	285±49	12±4	45±15
Zinc	6.5±2.6	29±11	2.4±0.9	46±18	6.0±1.4	23±5

The nature and amounts of the elements released to the atmosphere from sour gas plant incinerator stacks do not appear to create a critical emission problem in the surrounding neighborhoods. However, it is recommended that atmospheric dispersion modelling of the emissions from the three plants under study be carried out to more accurately assess the impact on receptors at ground level. Serious consideration should be given to the implementation of a comprehensive ambient air sampling program in areas where trace element concentrations are projected to be independent of sour gas plant emissions in order to establish typical background metal levels in different regions of Alberta.

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I. BACKGROUND

This study was initiated in response to a request by Dr. H.F. Thimm, Senior Environmental and Technical Advisor, Environment Protection Department, Energy Resources Conservation Board (ERCB) on June 15, 1982. The objectives and scope of this work were reviewed and defined in group discussion and telephone conversations by Dr. H.F. Thimm, Dr. A.W. Gnyp, P.Eng., and Dr. C.C. St. Pierre, P.Eng., of the Department of Chemical Engineering, University of Windsor.

In order to formulate a work plan, representative stack gas analyses, velocity measurements and sulphur dioxide emissions data from the following sour gas plants were employed:

a) Shell - Waterton(1)

b) Esso - Quirk Creek(2)

c) Shell - Jumping Pound(3)

d) Gulf - Strachan(4)

e) Canterra - Ram River(5)

Preliminary trace metal emission studies for the Shell - Waterton site(6-9) and three additional sulphur plant incinerator stacks (Shell-Innisfail; Hudson's Bay-Lone Pine Creek; Petrofina-Wildcat Hills(10)) were reviewed to assist in development of sample recovery and analysis procedures.

A formal proposal submitted on June 29, 1982 was accepted by the Energy Resources Conservation Board on July 19, 1982.

A. OBJECTIVES

The objectives of this investigation were to:

a) Conduct a trace element emission study at incinerator stacks of the sour gas plants located at

Shell - Waterton

Esso - Quirk Creek

Shell - Jumping Pound

Gulf - Strachan

Canterra - Ram River

Gulf - Pincher Creek*

b) Measure atmospheric dust levels using hi-vol samplers at one city and one rural location to establish background elemental concentrations

*Plant site added September 29, 1982.

c) Attend open houses in the Pincher Creek and Calgary areas during the month of October 1982.

d) Prepare a detailed written description of the proposed sampling and analytical methodology for review by a panel of chemists and chemical engineers chosen by the ERCB.

e) Present a seminar at a scientific meeting in the Calgary area, with invitations to interested scientists throughout Alberta, when arranged by the Board during the month of November 1982.

B. SCOPE

As a result of the initial meeting at the University of Windsor with Dr. H. Thimm on June 25, 1982, a review of the sulphur emission studies and preliminary heavy metal results, extensive literature research and personal discussions with members of Canadian and U.S. regulatory agencies, the testing program was divided into five distinct parts.

1. Preliminary Site Inspections

Preliminary site inspections were conducted at all designated sour gas sulphur plant incinerator stacks (except Gulf-Pincher Creek) by D.S. Smith,P.Eng., H.F. Thimm, Ph.D., and R.J. Farion, Senior Gas Plant Inspector or S. Slyman, Assistant Area Supervisor, ERCB during the week of July 12-16, 1982, to obtain the pre-test information specified by the Alberta Stack Sampling Code(11). The Gulf-Pincher Creek plant was inspected on September 30, 1982 by D. Smith and R. Farion. On the basis of these five initial visits, it became evident that:

a) a 17-ft. air cooled sampling probe was required for three stacks with diameters exceeding fifteen feet,

b) special port modifications were necessary to facilitate movement and support of the 17-ft. probe,

c) the location of refractory lined sampling ports were fixed but they could be adapted structurally to accommodate the required air cooled sampling probes,

d) the stack sampling personnel would be restricted by the limited platform extensions in place, consequently, innovative probe and train support systems had to be designed.

Following the field inspections and review of the sampling strategy, necessary modifications to sampling ports, monorail supports, guard rails, power and compressed air requirements were defined.

Engineering drawings and specifications were prepared and forwarded to the plant liaison at each site for implementation by plant operators in order to allow sampling to begin by August 19, 1982.

2. Preliminary Source Tests

Preliminary source testing was carried out at each incinerator stack to obtain:

a) the gas stream composition in terms of water vapour, carbon monoxide, carbon dioxide, nitrogen, argon, oxygen and sulphur dioxide

b) an estimate of total particulate concentration in the exhaust stream using an approved stack sampling train

c) the velocity distribution and total volumetric flowrate at the sampling port elevation

d) an estimate of the total particulate emission rate

e) elemental analyses of the samples recovered from four different locations in the sampling train at two different plants

These preliminary tests were necessary in order to facilitate isokinetic sampling of all stacks in accordance with the Alberta Environment Source Sampling Code(11). Two initial elemental analyses were conducted in order to determine the limits of detection for each element and to finalize the analytical methods.

3. Trace Element Emission Measurements

A minimum of three complete particulate emission tests were conducted at each of the five designated sour gas sulphur plant incinerator stacks using sampling procedures and equipment consistent with Alberta Environment requirements(11) or as mutually agreed to with Dr. H. Thimm, Energy Resources Conservation Board.

Sample recovery was done in four distinct parts involving:

a) nozzle-probe washings

b) filter catch

c) impinger assembly catch

d) cold trap catch

in order to provide an approximation of the particle size distribution and separation of gas phase versus solid phase trace elements in terms of the location of sample deposition in the train.

Each complete test provided:

a) gas stream composition in terms of water vapour, carbon monoxide, carbon dioxide, nitrogen, argon, oxygen and sulphur dioxide

b) the local velocity distribution and total volumetric flowrate

c) suitable samples for elemental analyses

d) the individual trace element concentrations

e) the individual trace element emission rates

4. Trace Element Analyses

For every particulate emission test the samples collected at each of the four distinct parts of the train was analyzed for the trace elements listed in Table 1.1.

Element (Symbol)

Lithium (Li)
Thallium (Tl)
Chromium (Cr)
Titanium (Ti)
Vanadium (V)
Manganese (Mn)
Iron (Fe)
Cobalt (Co)
Nickel (Ni)
Copper (Cu)
Zinc (Zn)
Germanium (Ge)
Gallium (Ga)
Arsenic (As)

Element (Symbol)

Selenium (Se)
Molybdenum (Mo)
Cadmium (Cd)
Antimony (Sb)
Mercury (Hg)
Lead (Pb)
Strontium (Sr)
Beryllium (Be)
Boron (B)
Indium (In)
Tellurium (Te)
Silver (Ag)
Aluminum (Al)
Scandium (Sc)
Tin (Sn)

Table 1.1. Trace Metals of Interest

These elements were selected after a comprehensive review of open literature and discussions with personnel from Canadian and American regulatory agencies as well as ERCB representatives.

For common metals (exclusive of hexavalent chromium, arsenic, selenium, mercury and vanadium) the samples were ultimately disssolved in dilute hydrochloric or nitric acid and the resulting solutions were analyzed by an atomic absorption spectrophotometer using a hollow cathode lamp for the specific metal. Two recoveries and two laboratory blanks were analyzed with each series of samples.

Samples of arsenic, selenium and vanadium were analyzed using a furnace (electrothermal) technique which yields greater sensitivity and lower limits of detection (12) than direct flame atomization. Mercury was determined using the cold vapour method in which mercury vapour was generated with 20% stannous chloride for purging into the atomic absorption detection cell.

Split samples from the Canterra-Ram River Gas Plant were analyzed for two data sets by a second independent laboratory for interlaboratory comparisons.

5. Atmospheric Dust Levels

High volume dust samplers were used to establish atmospheric dust levels at two mutually agreed upon locations representing urban and rural sites where trace element concentrations were projected to be unaffected by sour gas plant emissions.

Twenty-four hour samples were collected at each site according to EPA Reference Methods(13) for elemental analysis of the filter catches.

II. SOURCE SAMPLING METHODOLOGY

A. INTRODUCTION

A literature search and personal discussions with Canadian and United States regulatory personnel indicated that an approved source sampling reference method(s) did not exist for measuring trace elements in stationary source emission streams. Several publications(12, 13-17) and personal contacts(18-20) indicated that many of the potentially hazardous metal species present at trace levels in emission streams are largely of submicron particle size (0.1-1.0 microns in diameter). This size corresponds to the lower collection efficiency of stack sampling train filters and pollution control devices.

The large stack diameters (up to 20 feet) and elevated stack temperatures (800-1,200°F) also presented significant probe design challenges. The most critical problem was successful incorporation of a glass liner which would insure minimal sample contamination and facilitate sample recovery.

In order to develop suitable sampling and analytical methodologies for trace levels of metals the following objectives had to be met:

a) collection of a representative sample

b) minimization of sample loss in the train and contamination by sampling train components

c) quantitative recovery of the sample from all parts of the train

d) development of suitable sample pretreatment procedures to achieve solubilization, concentration and negligible interference

e) development of suitable analytical procedures to carry out instrumental analysis of trace metals in the presence of unknown amounts of other particulate matter.

Collection of a representative sample and minimization of contamination are discussed here. Every effort was made to follow the Alberta Environment Stack Sampling Code Reference Methods (AERM)(11). Due to the size and complexity of the sampling train, the need for meticulous sample recovery procedures, and restrictive platform dimensions, three samplers were initially used at the incinerator stacks.

The source testing supervisor, Mr. D. Smith, was present for all tests. He is a registered Professional Engineer in the Province of Ontario with a Master of Applied Science degree in Chemical Engineering and ten years relevant experience. All team members had successfully completed a suitable source sampling course and possessed relevant engineering backgrounds (including Ph.D. and M.ASc. degrees).

B. LOCATION OF SAMPLING PORTS AND POINTS

1. Port Location

The sampling ports and platforms were already installed at all sour gas plant incinerator stacks. Their locations provided the vertical straight lengths downstream and upstream from the nearest flow disturbances listed in Table 2.1.

Plant Location	Stack Diameter (ft)	Number of Ports	Distance to Nearest Disturbance Downstream	Upstream
			Stack Diameters	
Gulf-Strachan	15.7	4	8	2
Canterra-Ram River	20.1	4	4.6	2
Shell-Jumping Pound	5.5	2	8	2
Shell-Waterton	15.1	2	6.2	2
Gulf-Pincher Creek	4.3	2	8	2

Table 2.1 Sampling Port Characteristics

The preferred sampling site according to the AERM No. 1(11) is at least eight stack diameters downstream and a minimum of two diameters upstream from the nearest flow disturbance. When these conditions were not satisfied, the number of sampling points was increased above the minimum requirements specified by AERM.

2. Port Design

The sampling ports and/or platforms at all plants required a variety of minor modifications in order to support the train monorail, eliminate obstructions in the sampling train travel path and to standardize to 4-inch diameter Schedule 40 male - threaded pipe nipples. Preliminary field inspections were conducted at all sites to allow preparation of engineering drawings and specifications for submission to plant operators who arranged the necessary changes.

Special port adaptations were necessary to facilitate movement and support of the 17 foot sampling probe required for the stacks with diameters exceeding 15 feet . This probe length was necessary, even though four ports were installed, since these large diameter stacks were designed with inner steel linings and outer concrete shells having annuli ranging from 7 1/2 to 11 feet as illustrated in Figure 2.1. Probe alignment and movement were facilitated by construction and installation of new 4-inch Sch 40 pipe sampling ports of the required length fitted with two sets of rollers as illustrated in Figure 2.2. The 4-in. ports were fitted with end caps to seal the opening when the ports were not in use.

3. Number and Location of Sampling Points

The number and location of traverse points were determined according to AERM No. 1(11) in order to provide the required number of equal sampling areas, as illustrated in Figure 2.3. When the upstream distance to the nearest disturbance was greater than 8 diameters Table 2.2 was used. For stacks with less than 8 diameter distances, Figure 2.4 was employed to increase the required number of sampling points. Table 2.3 facilitated location of the points on a diameter for up to 24 points per traverse. The following equation:

$$R = 100\left(0.5 - \sqrt{\frac{2n-1}{4N}}\right)$$

where: $n = \frac{N}{2} + (1-h)$

R = percentage of stack diameter from port
h = sampling point number from port
N = number of sampling points per traverse

was used to extrapolate Table 2.3 when 26 or more points were required on a traverse.

C. DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE

Method 1 (AERM)(11) was followed during measurement of local stack velocities needed to calculate the total volumetric flowrate through the incinerator stack at the sampling elevation.

All velocity measurements were made using an S-type Pitot tube. A calibrated sheathed resistance thermometer (RTD), attached to the probe assembly allowed simultaneous temperature and velocity pressure measurements. The Pitot tube coefficients were obtained

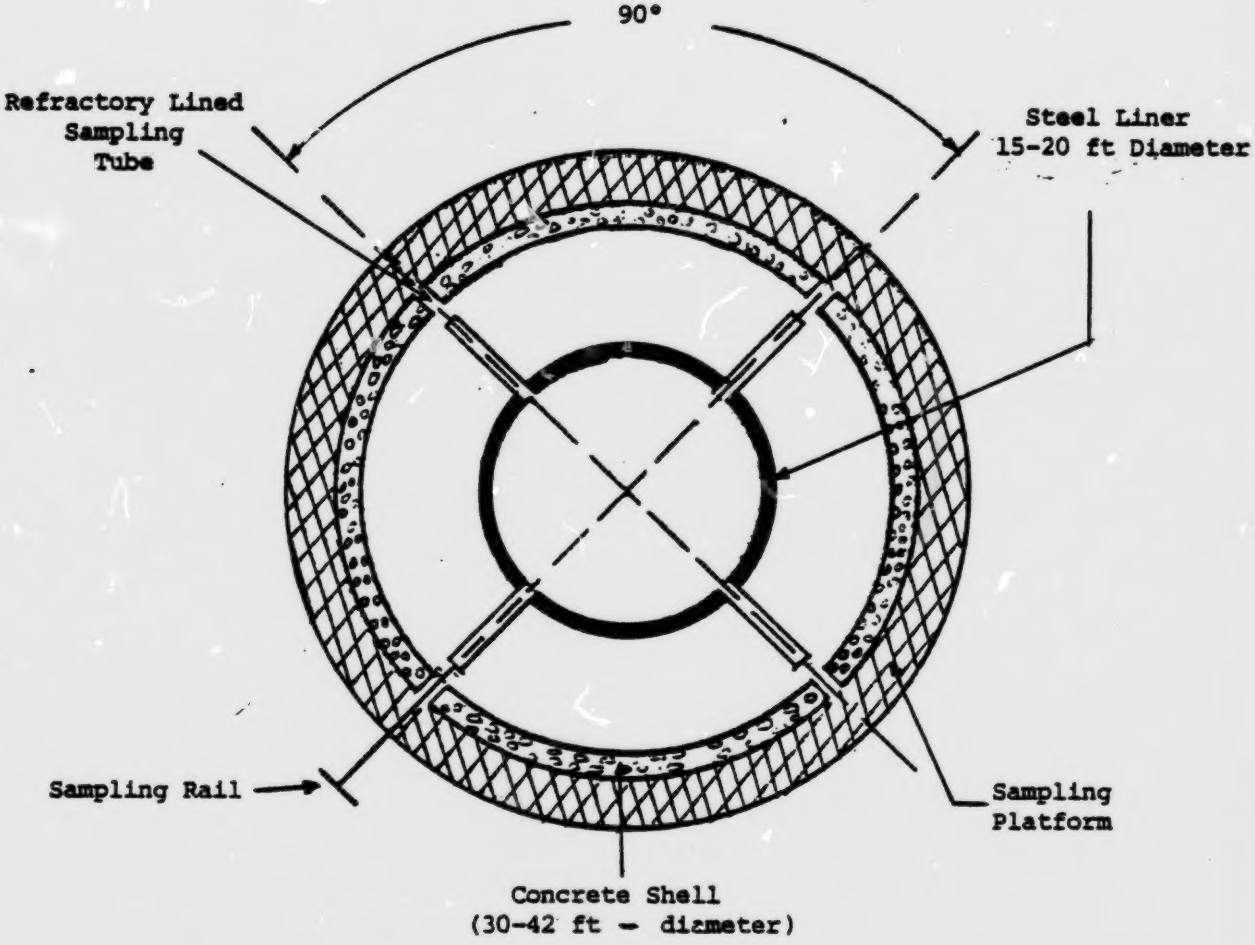
90°
Refractory Lined Sampling Tube
Steel Liner 15-20 ft Diameter
Sampling Rail
Sampling Platform
Concrete Shell (30-42 ft — diameter)

Figure 2.1 Detail of Incinerator Stack at Sampling Platform Elevation

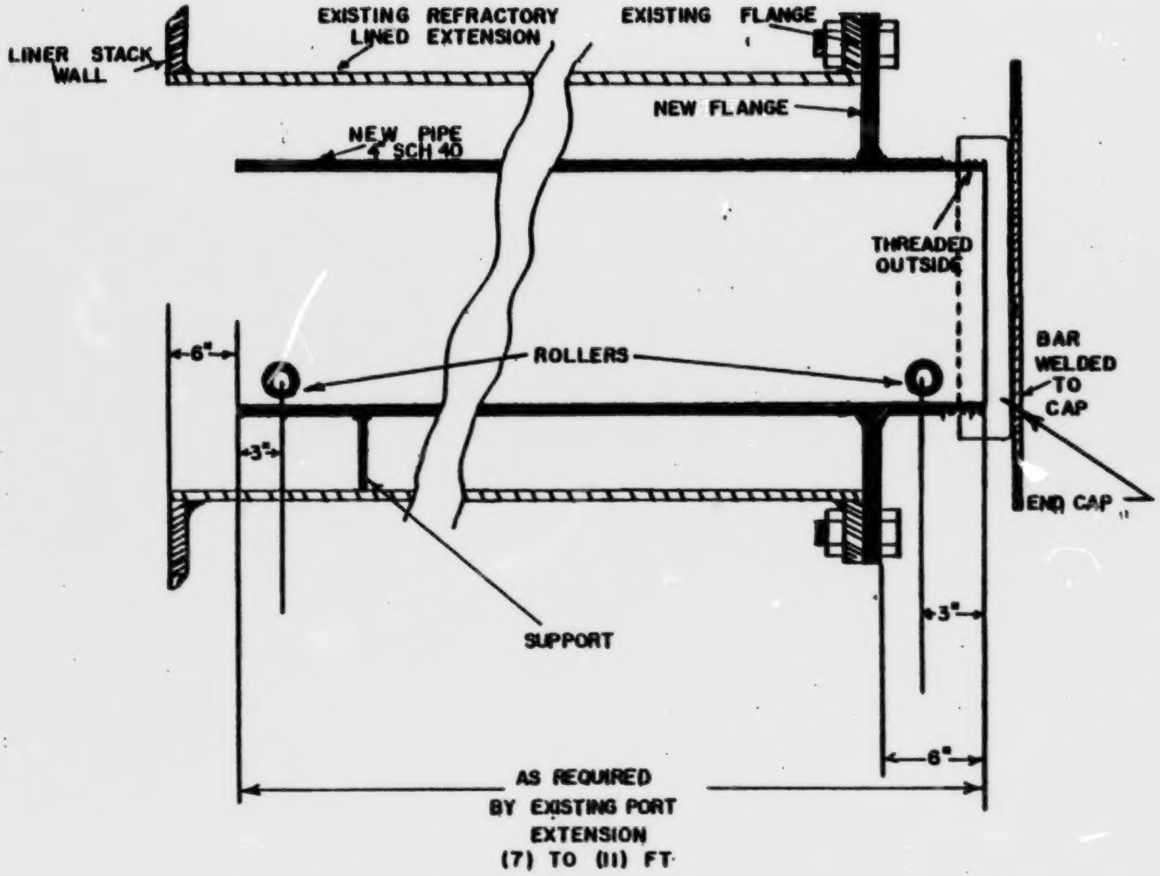

Figure 2.2 Modifications to Existing Sampling Ports

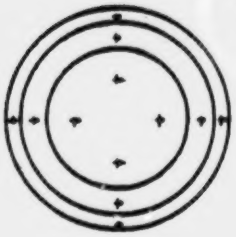

Figure 2.3

Cross-Section of Circular Stack Divided into Equal Areas with Traverse Points Located at Center of Each Area

Stack Diameter, Ft.	Minimum Number of Sampling Points Required per Traverse
*Less than 1	2
1<I.D.≤2	4
2<I.D.≤4	8
4<I.D.≤8	12
8<I.D.≤16	16
Greater than 16	Refer to Alberta Environment for approval before testing.

I.D. = Inside diameter of stack

Table 2.2
Minimum Number of Traverse Points for Sampling Stacks (11)

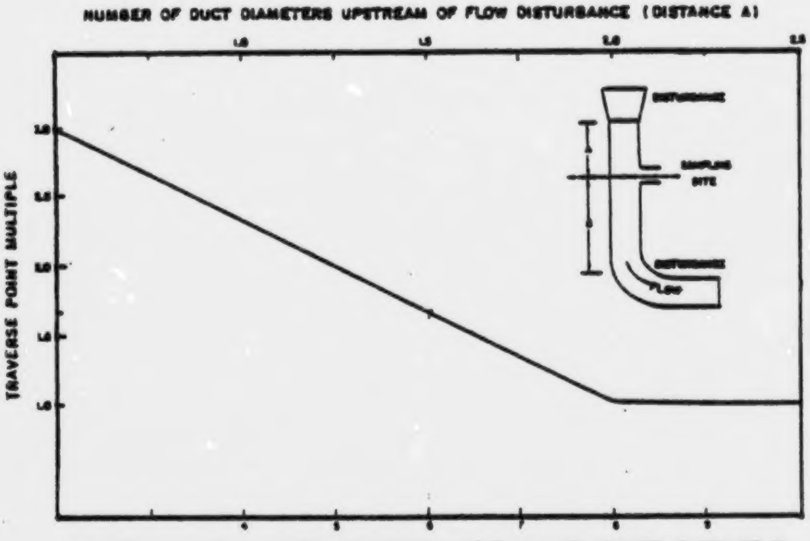

Figure 2.4
Traverse Point Multiples to Determine Minimum Number of Traverse Points Required When A < 2 or B < 8 (11)

Percent of Stack Diameter from Inside Wall to Traverse Point

Traverse Point Number On A Diameter	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.3	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.7	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.5	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.5	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.3	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.5	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.5	36.6	28.3	23.6	20.4	18.0	16.1
8				96.7	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.1	23.0
10					97.5	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.9	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

Table 2.3 Location of Traverse Points in Circular Stacks

for all the RTD/Pitot tube/sampling nozzle combinations, as illustrated in Figure 2.5, using the wind tunnel located in the University of Windsor Department of Mechanical Engineering. The procedure described in Appendix 2A, Method 2, of the Ontario Source Testing Code(21) was followed.

Since the 17-ft probe could not fit into the wind tunnel an exact replica of shorter overall length employing the actual component parts, was fabricated to allow proper calibration. The 8-ft effective length probe was calibrated exactly as used in the field.

An inclined manometer with a readability of 0.1 inches of water was employed to measure the velocity pressure. Barometric pressures were obtained from the plant laboratory for each sampling period.

The absence of cyclonic and/or flow reversals was confirmed at all sampling locations.

D. DETERMINATION OF STACK GAS COMPOSITION AND MOLECULAR WEIGHT ON A DRY BASIS

The molecular weight of the exhaust gas stream on a dry basis required for use in Method 5 (AERM)(11) was calculated employing on-site gas chromatographic analyses.

1. Gas Chromatographic Analyses

Integrated ten minute samples were collected by drawing air with a Neptune Model 4K vacuum pump into an 18 litre Tedlar sampling bag. The gas composition in terms of carbon dioxide, carbon monoxide, oxygen, and nitrogen was determined with a Carle Model AGC III gas chromatograph equipped with 1/4-inch by 2-feet long Porapak Q (100-200 mesh) and 1/4-inch by 6-foot long molecular sieve 13X columns. One side of the thermal conductivity detector was located between the Porapak Q and molecular sieve columns while the other side was at the outlet of the molecular sieve column. The instrument, operated isothermally at 55 °C with a helium flowrate of 40 cm^3/min, was calibrated with a known mixture of nitrogen, oxygen, carbon dioxide, and carbon monoxide. The standard gas was prepared by Western Research and Development. Its composition was checked by an independent analysis carried out by DB Robinson & Associates, Ltd. of Edmonton, Alberta. Appendix I documents the results of the calibration of the standard gas. Analysis was performed on 1000 microlitre injections immediately following each test run.

2. Sulphur Dioxide

Sulphur dioxide concentrations in the exhaust stream were obtained by following Method 5 (AERM)(11) for sulphur dioxide emission measurements only. A constant sampling rate of approximately 0.1 cubic feet per minute was employed to

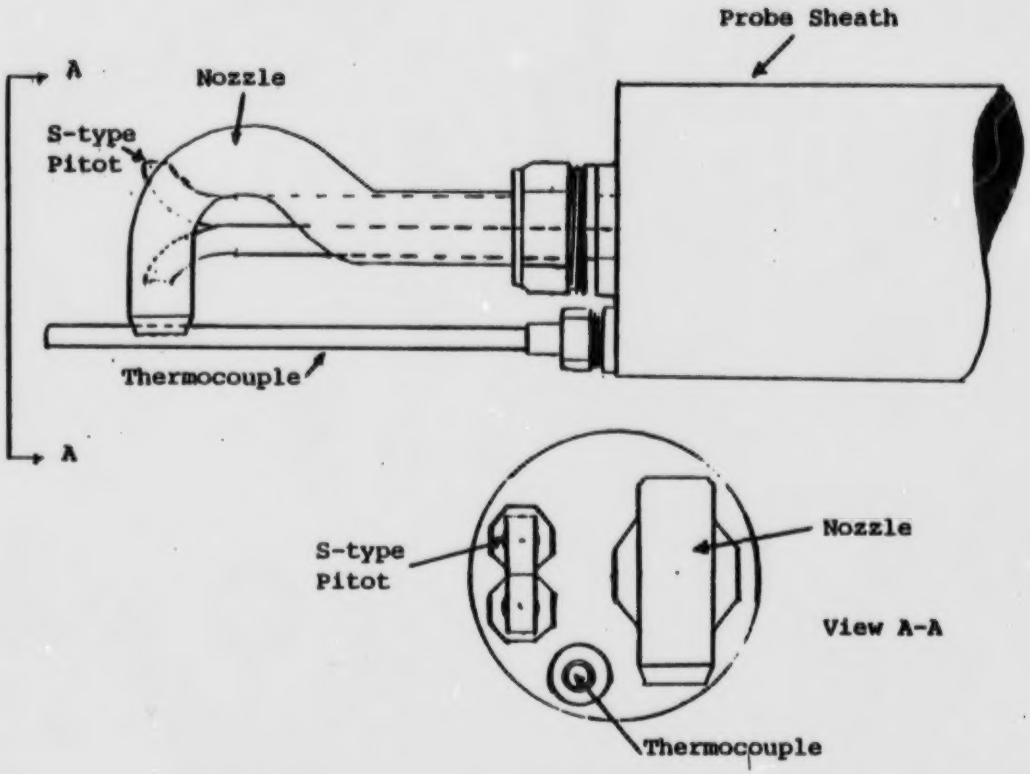

Figure 2.5 Relative Position of RTD/Pitot Tube/Sampling Nozzle Used in Calibration and Sampling

provide total sample volumes of 2 to 6 cubic feet. After sampling, the two midget impingers containing 3% hydrogen peroxide were transferred, along with impinger rinses, to 25 ml glass sample vials fitted with Teflon caps.

In the laboratory, analysis was accomplished by the technique outlined in Method S308 of the NIOSH Manual of Analytical Methods(22), in which isopropyl alcohol is added to the samples. The pH of each sample is adjusted with perchloric acid, and the sulfate content of each sample determined by titration with barium perchlorate solution using Thorin indicator. Results of analyses (calculated as SO_2), which include any necessary correction for blank determinations run in parallel with the analysis, were used in conjunction with field sampling data to calculate the reported concentrations of sulphur dioxide. This analytical method is consistent with Method 5 (AERM)(11) requirements.

E. DETERMINATION OF MOISTURE CONTENT

The moisture content of a stack gas was obtained employing the condensation method of Method 3 (AERM).(11) This determination was made simultaneously with the particulate (trace element) sampling programme.

The mass of condensate collected in the impingers and dessicant (Drierite) was determined by weighing all containers before and after sampling to the nearest 0.1 gm.

This water mass was converted to an equivalent gaseous volume. The volume fraction of moisture in the stack gas is calculated using the corresponding total gas sample volume at reference conditions (530°R, 29.92 inches Hg).

F. DETERMINATION OF PARTICULATE EMISSIONS

The measurement of particulate emission rates according to Method 4 (AERM)(11) requires isokinetic sampling and particulate separation from the extracted gas stream using dry filter media and wet scrubbing in a series of impingers, using the basic sampling train illustrated in Figure 2.6. In order to extract and transport the samples from the stack to the collection media with minimal contamination, a glass liner was used. For sour gas incinerator stacks, having gas stream temperatures in the 800 to 1,200°F range, two custom gas cooled probes were designed and constructed. The use of acid solutions in the impingers and the addition of two impingers kept at the dry ice-acetone temperature, helped to promote submicron particulate removal.

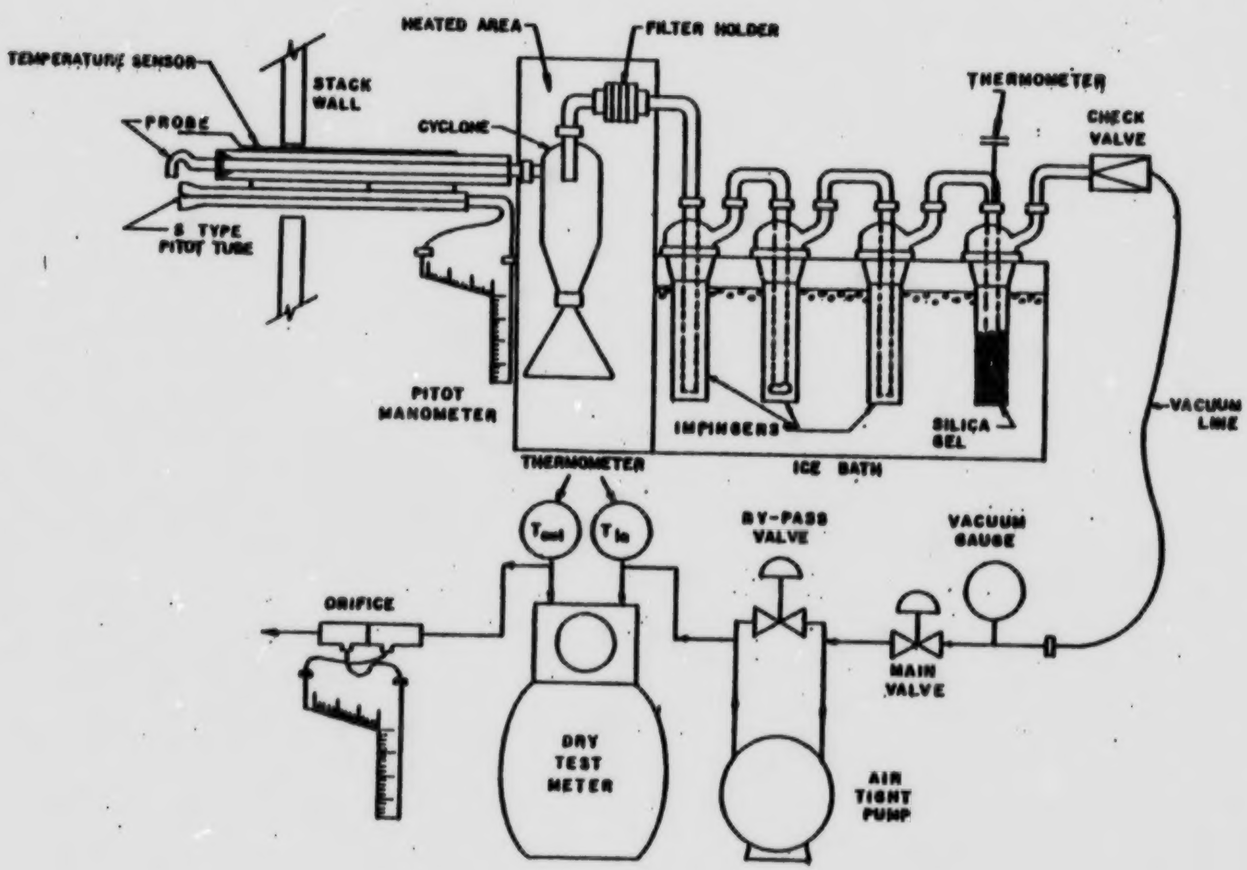

Figure 2.6 Basic Sampling Train for Particulate Matter

The recommended isokinetic sampling procedures of AERM No. 4 were followed for all particulate emission tests. Preliminary tests were not always isokinetic. The leak check for the 17 foot probe had to be modified since the recommended procedure could not be performed on the sampling platform due to space limitations. Sample recovery and analyses, which were much more rigorous than those required for the usual particulate matter sampling tests, are described in detail in the next two sections.

All substantial modifications to the sampling apparatus and procedures of Method 4 are described in detail here. The choice of components and absorbing solutions represents an optimum in terms of a single procedure for sampling and pretreatment of all the elements of concern, although, such pretreatment might not be best on an individual element basis.

1. Apparatus

The sampling train employed is schematically illustrated in Figure 2.7.

a) Pitot Assembly

Two custom air cooled probes were fabricated in the University of Windsor, Chemical Engineering Workshop, by Mr. G. Ryan. Figure 2.8 details the probes in cross-section and plan. Sheathed, remote temperature devices (RTD) capable of withstanding the high gas stream temperatures and compatible with the existing electronics of the temperature readout units were incorporated into the probe assemblies.

Sampling nozzles of the button-hook type were constructed of 316 stainless steel. They were the only components of the train not made of glass that contacted the extracted gas sample stream.

Borosilicate glass was selected for the 5/8-in. glass probe liners since it could withstand more mechanical and thermal shock than Vycor.

The approximate composition of the borosilicate glass probe is provided in Table 2.4. Tests have shown(23) minimal trace element leaching by acidic solutions similar to those employed during this study for sample recovery.

A 5/8-in. diameter 316 stainless steel liner was also constructed to provide a back-up capability if the gas-cooled probe could not provide sufficient thermal shock protection to the glass liner.

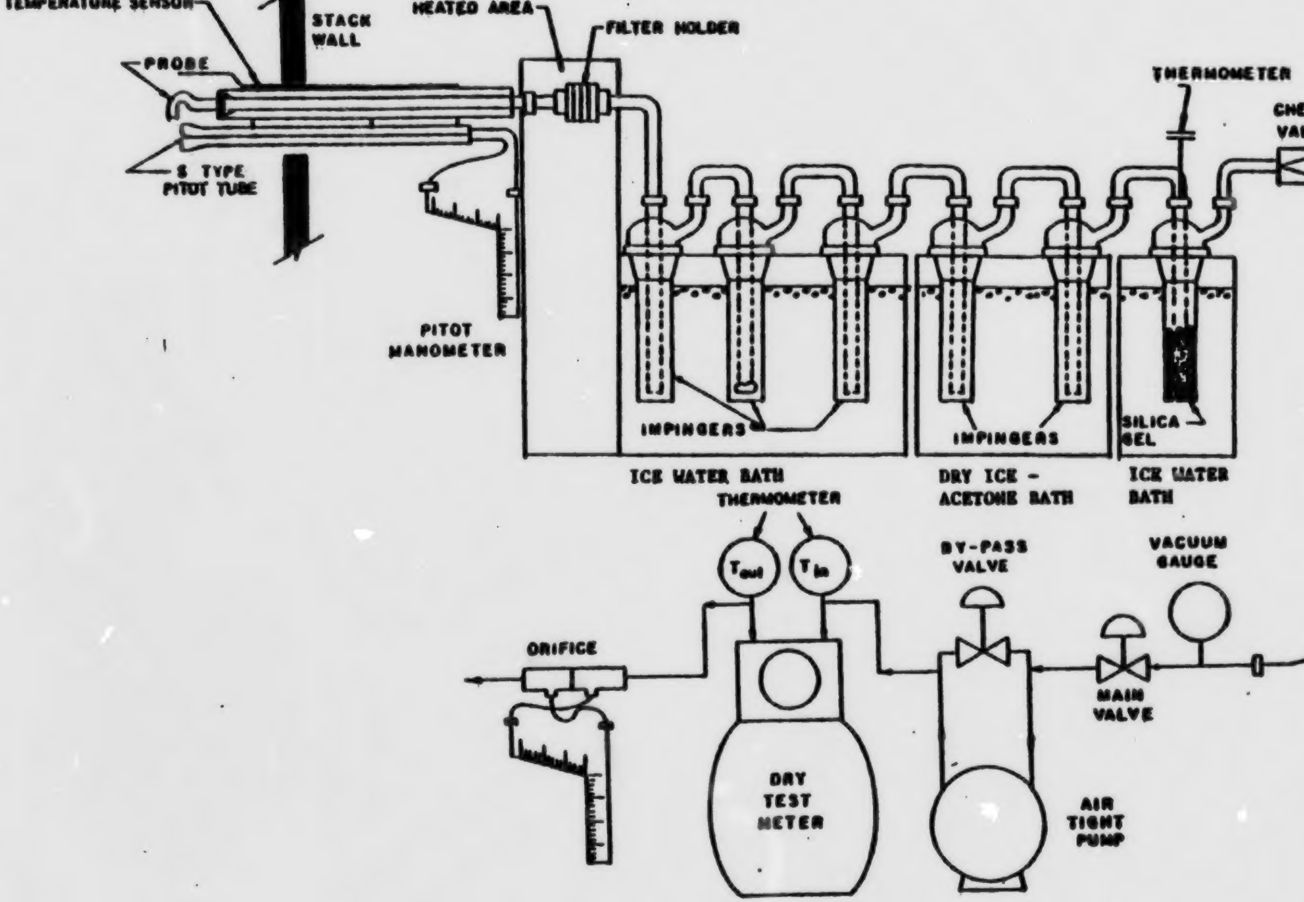

Figure 2.7 Sampling Train for Trace Metals

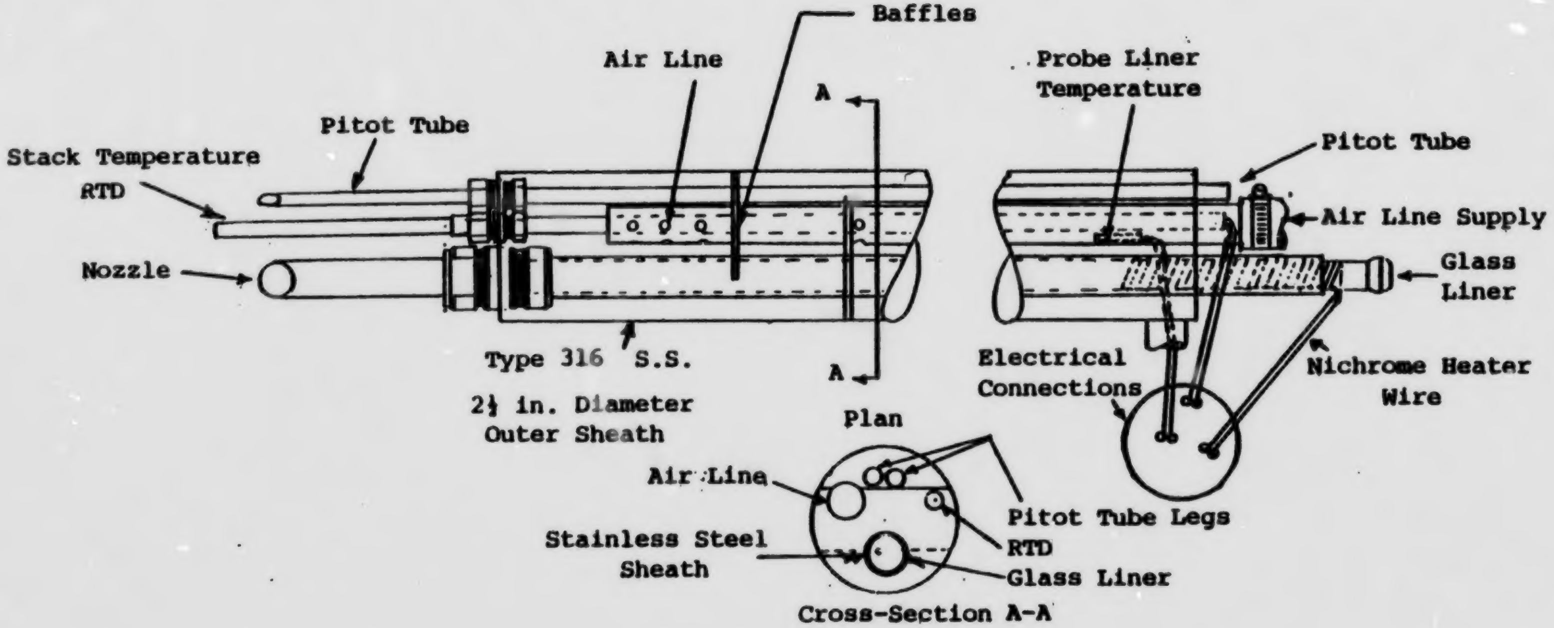

Figure 2.8 Plan and Cross-Sectional Views of Air Cooled Probe

Composition (%) by weight

SiO_2	B_2O_3	Al_2O_3	Na_2O	K_2O
80.5	12.9	2.2	3.8	0.4

Physical Properties

Softening Temp. ^oF	Annealing Temp. ^oF	Strain Temp. ^oF	Maximum Temp. ^oF	Specific Gravity	Coefficient of Linear Expansion $F^{-1}x10^7$
1508	1027	950	932-1022	2.23	18

Table 2.4. Approximate Composition and Physical Properties of Borosilicate Glass Probe. (24)

The annular flow area between the outer stainless steel sheath and inner protective tube containing the glass liner was baffled to enhance heat removal. The back half of the probe was wound with Nichrome heating wire to ensure that no condensation occurred in the probe length exposed to the ambient atmosphere. Cooling air was provided by a self-contained Fuji Ring Compressor Model VFC 302P-5T centrifugal blower with a capacity of 30 cubic feet per minute or plant compressed air supplied at the sampling platform level. The cooling air flow rate was adjusted to achieve the necessary balance between heat removal consistent with glass probe liner protection and excessive cooling leading to possible condensation.

All Pitot-RTD-nozzle combinations were calibrated (for all possible sampling nozzle diameters) prior to and following field use to derive the S-type pitot tube coefficients corresponding to actual use in the sampling programme(21).

b) Filter and Cyclone

A cyclone was not used as a sampling train component since previous studies indicated that particulate sizes were not sufficiently large to be captured by the normal cyclone design employed in stack sampling trains. The glass probe liner was connected directly to the 12.5 cm diameter filter holder with a cyclone by-pass constructed of Pyrex glass.

Several filter media have collection efficiencies greater than 99% (for 0.3 micron dioctyl phthalate particles) for face velocities of 12 to 125 cm/s. The conventional glass fibre filter material manufactured by Reeve Angel (Whatman, Inc.) Type 934 AH and the Ultra-Pure QM-A quartz micro fibre filters, supplied by Whatman were selected for blank metal checks (See Appendix I for technical data). A special run of the 12.5 cm diameter QM-A-quartz micro fibre filters was made by Whatman who supplied 100 without cost for this study.

The QM-A-quartz filters, which were found to have lower trace element concentrations in the series of blank analyses conducted in the laboratory, were used in this study. For 0.3 micron dioctyl phthalate smoke particles the QM-A-quartz materials were found to have 99.95% collection efficiency(25).

c) Impinger Train

The order and contents of the normal impinger train specified by AERM No. 4 are summarized in Table 2.5.

Impinger Number	Type	Contents g
1	Modified	100 distilled deionized water
2	Greenburg-Smith	100 distilled deionized water
3	Modified	Empty
4	Modified	250-dessicant

Table 2.5 Method 4 Impinger Train

All impingers were immersed in an ice-water bath to condense water vapour for purposes of determining the moisture content of the gas stream and to enhance capture of submicron particulate passing through the filter.

For this trace element sampling program two additional impingers were added to the basic particulate matter sampling train providing the knock-out and absorption train detailed in Table 2.6:

Impinger Number	Type	Contents g	Immersion Bath Temperature (°C)
1	Modified	100 6 M nitric acid	0
2	Greenburg-Smith	100 6 M nitric acid	0
3	Modified	Empty	0
4	Modified	Empty	-80
5	Modified	Empty	-80
6	Modified	250-dessicant	0

Table 2.6 Trace Element Impinger Train

Although a mixture of nitric and hydrochloric acids would be superior for dissolution of the trace metals, the presence of chloride during evaporation of the excess acid could result in significant losses of volatile halides (arsenic, selenium and vanadium). A six molar nitric acid concentration was chosen since this strength was successfully employed in an earlier study(12). Eight molar(25) concentrations have also been employed by previous investigators.

Deionized, distilled water, provided by the Energy Resources Conservation Board laboratory in Edmonton, was prepared following the procedure outlined in Appendix II. Trace metal grade Baker nitric acid from Lot No. 218042 was used to prepare the 6M solutions. Appendix II summarizes the composition of this reagent.

The last impinger contained Drierite (mesh size 10-20) which was discarded after each run. Loss of moisture removal capacity and erroneous moisture levels were readily detected by the blue to pink colour change.

d) Control Module

An approved EPA Model No. CU-4 sampling train manufactured by Andersen Samplers, Inc. was employed to sample isokinetically. The Pitot tube coefficients, orifice meter flow factor and dry gas meter correction factor were determined prior to field use on August 13 and 17, 1982 employing calibration procedures recommended in Method 7 of the AERM.(11) Post calibration of the train was performed on October 26, 1982.

Isokinetic sampling within ±10% at every point in each traverse was verified following the Method 4 procedure.

e) Leak Test

The 8-foot gas cooled probe was leak tested before each sampling traverse following AERM No. 4.(11) However, space limitations on the sampling platform precluded using this method for the 17-foot probe. The leak test for this probe was conducted by plugging the nozzle, pulling a 15-in. Hg vacuum on the probe alone and monitoring for leaks by observing the pressure gauge for a period of a minute. Any leak was readily detected within this time. The probe was inserted into the stack, with the impinger case suspended on the traversing rail. Then the remainder of the train was leak tested by plugging the ground glass joint, which connects to the probe in the oven, following the Method 4 procedure.

f) Sampling Conditions

Table 2.7 summarizes the relevant ranges of the total number of sample points, sampling times per point, total sample volumes, total sampling times and sampling rates employed in this study.

Total number of sample points:	20-48
Sampling time per point:	6 - 8 min
Total sample volumes:	75-150 ft^3 at reference conditions
Total sampling times	120-288 min
Sampling rates	0.3-0.7 ft^3/min

Table 2.7 Summary of Test Conditions.

A complete test for a plant consisted of a preliminary survey and a minimum of three particulate matter emission rate measurements.

G. PROCESS DESCRIPTION AND SOUR GAS PLANT OPERATING CONDITIONS

In order to allow effective correlation of incinerator stack emissions to plant operating conditions, Mr. R. Farion, Senior Gas Plant Inspector with the ERCB, was present in the control room for all tests and in constant touch with the source sampling team. Before, during and for several hours after each test run the information summarized in Table 2.8 was recorded on an hourly basis. In addition, Mr. Farion obtained process flow sheets, descriptive technical literature describing the process, engineering drawings of the stack detailing breeching elevations relative to sampling ports, plan views of the stack indicating stack diameter at the sampling level and a plot plan of the site indicating the stack position relative to plant boundaries for each plant tested.

RAW GAS INLET FLOW RATE
PLANT SALES GAS FLOW RATE
FEEDRATE TO SULPHUR PLANT
FEED TO FLARE STACK
STACK TEMP. (TOP AND BOTTOM)
STACK FLOW RATE
SO_2 CONCENTRATION

Table 2.8 Process Information Obtained at Each Plant on an Hourly Basis for Each Test Run.

1. Strachan Gas Plant (Gulf Oil Canada Limited)

The simplified flow schematic of the Strachan Gas Plant shown in Figure 2.9 summarizes the processes described in Figures 2.10, 2.11, 2.12, 2.13, and 2.14.

Raw sour gases carrying quantities of water and liquid hydrocarbons are deliquified in the Inlet Separator (1). The, esentially , liquid free sour gas stream is fed to the Amine Contactors (2) operating at approximately 1,000 psi for removal of hydrogen sulfide (H_2S) and carbon dioxide (CO_2) through absorption in the aqueous amine solution. The sweetened gases are passed through Dehydrators (3) for removal of the last traces of moisture. The dried sweet gas stream is then directed to the H/C Separator (4) where the heavier molecular weight hydrocarbons are removed for use as a reflux stream in the De-ethanizer (5) designed to remove essentially similar high boiling hydrocarbons from the dried sweet gas street leaving the H/C Separator (4). The overhead stream from the De-ethanizer (5) represents sales gas delivered to the pipeline distribution system at a pressure of 870 psia.

The spent amine solution leaving the Amine Contactors (2) is fed to Amine Regenerators (6) where the acid gases [hydrogen sulfide (H_2S) and carbon dioxide (CO_2)] are distilled to leave fresh amine solution for recirculation to the Amine Contactors (2). The essentially dry acid gases (H_2S and CO_2) from the Amine Regenerators (6) are partially incinerated in the Acid Gas Furnace (7) before entering the Sulfur Converters (8). The gaseous sulfur produced in the Converters (8) is condensed in Sulfur Condensers (9) for ultimate casting in solid sulfur block piles until shipment from the plant. Uncondensed sulfur fumes and converter tail gases are directed to the Tail Gas Separator (10) for additional recovery of elemental sulfur. The tail gases, still containing some unconverted hydrogen sulfide (H_2S), are burned in the Incinerator (11) to minimize the emission of hydrogen sulfide (H_2S) through the Incinerator stack (12).

The Sour Condensate Separator (13) removes water carried over from the Inlet Separator (1) to produce a relatively moisture free hydrocarbon stream that can be fed to the Sour Condensate Stripper (14). Sour gases recovered from the Sour Condensate Stripper (14) and the Sour Condensate Separator (13) are recycled to the Inlet Gas Separator (1). The sour condensate leaving the Sour Condensate Stripper (14) is mixed with the bottoms stream from the De-ethanizer (5) for processing in the Stabilizer (15). Stabilization involves distillation to produce a heavier, high boiling, condensate fraction that is fed to the pipeline system and the lower molecular overhead components that are separated into sales gas and liquefiable petroleum gases (LPG) in the Stabilizer Reflux Condenser (16) .

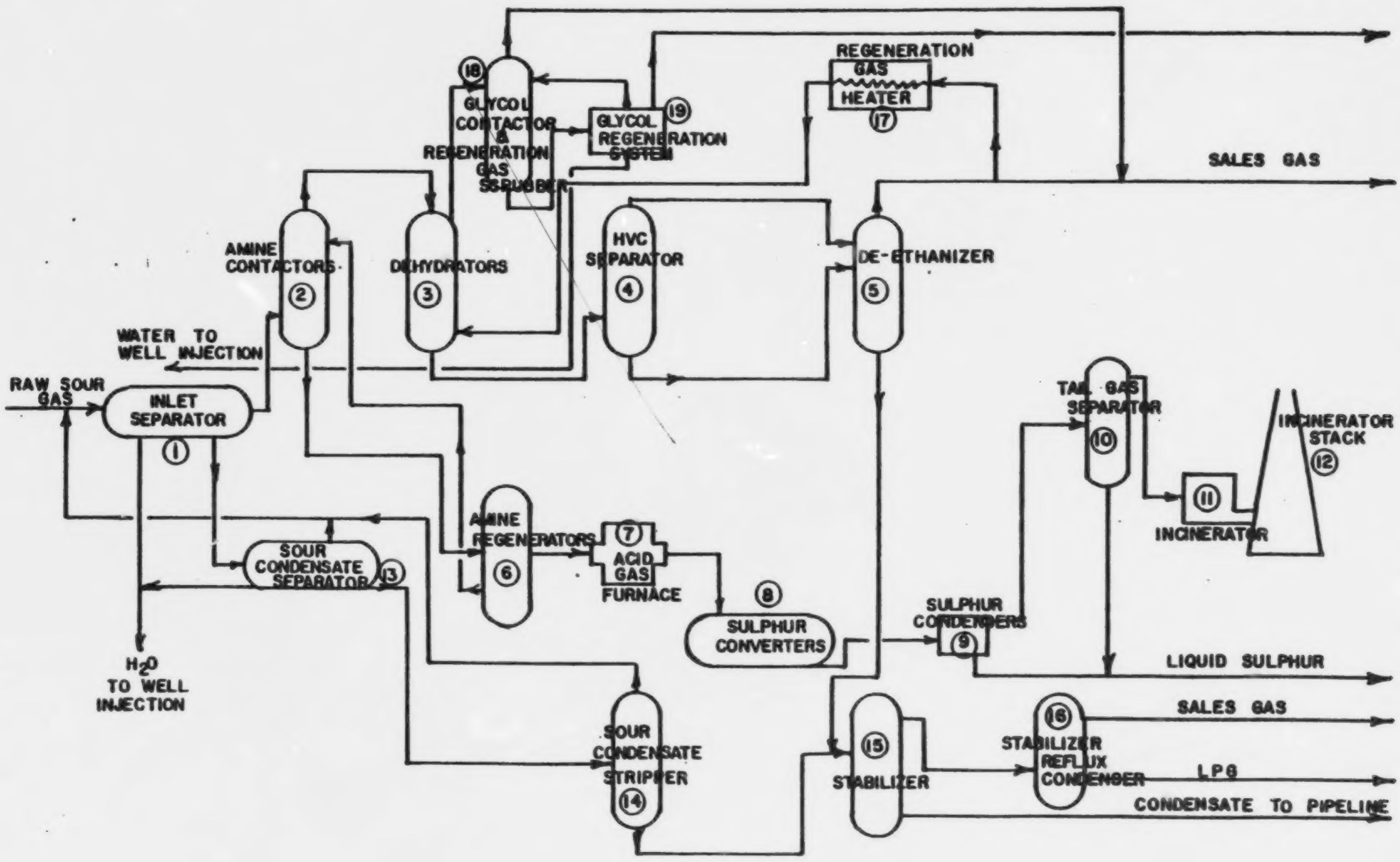

Figure 2.9 Simplified Flow Schematic of Strachan Gas Plant

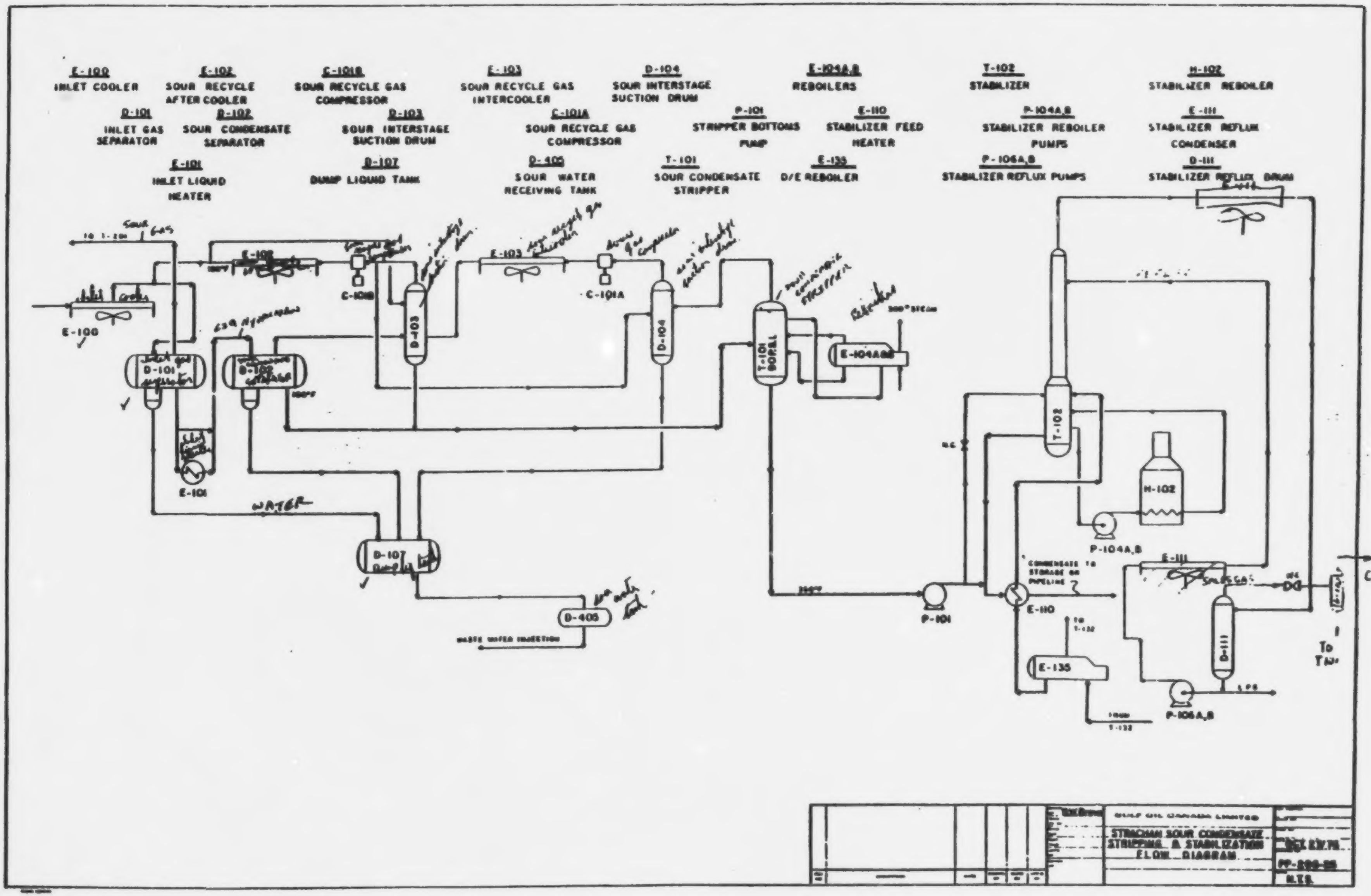
E-100 INLET COOLER
E-102 SOUR RECYCLE AFTER COOLER
C-101B SOUR RECYCLE GAS COMPRESSOR
E-103 SOUR RECYCLE GAS INTERCOOLER
D-104 SOUR INTERSTAGE SUCTION DRUM
E-104A,B REBOILERS
T-102 STABILIZER
H-102 STABILIZER REBOILER
D-101 INLET GAS SEPARATOR
D-102 SOUR CONDENSATE SEPARATOR
D-103 SOUR INTERSTAGE SUCTION DRUM
C-101A SOUR RECYCLE GAS COMPRESSOR
P-101 STRIPPER BOTTOMS PUMP
E-110 STABILIZER FEED HEATER
P-104A,B STABILIZER REBOILER PUMPS
E-111 STABILIZER REFLUX CONDENSER
E-101 INLET LIQUID HEATER
D-107 DUMP LIQUID TANK
D-405 SOUR WATER RECEIVING TANK
T-101 SOUR CONDENSATE STRIPPER
E-135 D/E REBOILER
P-106A,B STABILIZER REFLUX PUMPS
D-111 STABILIZER REFLUX DRUM
Sour GAS
TO T-201
E-100
D-101
E-101
E-102
D-102
C-101B
D-103
E-103
C-101A
D-104
T-101 SOR&L
E-104A&B
300° STEAM
WATER
D-107
D-405
WASTE WATER INJECTION
T-102
H-102
P-104A,B
P-101
E-110
CONDENSATE TO STORAGE OR PIPELINE
E-135
E-111
SALES GAS
D-111
P-106A,B
LPG
TO C102
TO T...
GULF OIL CANADA LIMITED
STRACHAN SOUR CONDENSATE STRIPPING & STABILIZATION FLOW DIAGRAM
PP-200-25
N.T.S.

Figure 2.10 Strachan Sour Condensate Stripping and Stabilization Flow Diagram

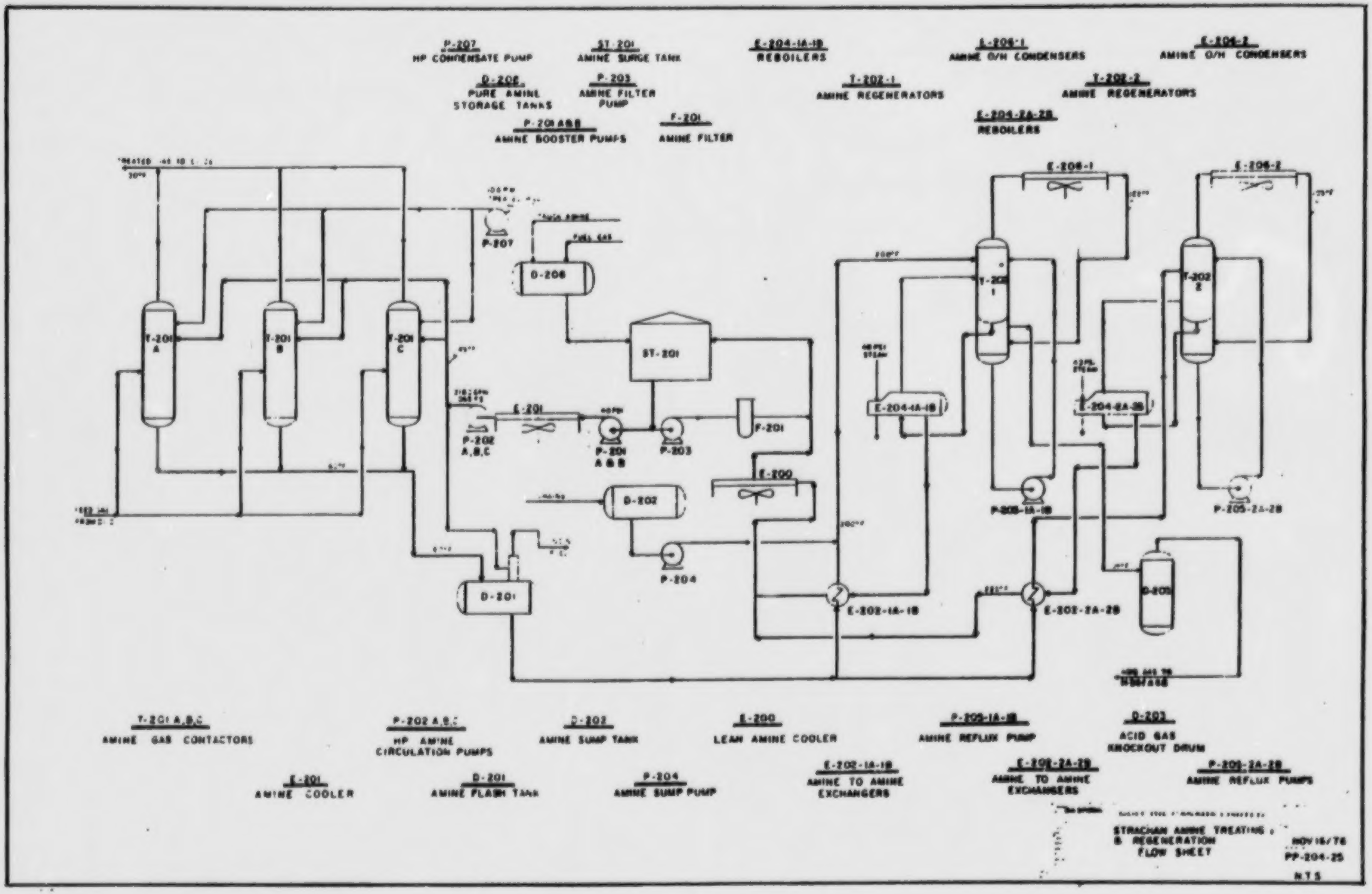

Figure 2.11 Strachan Amine Treating and Regeneration Flow Sheet

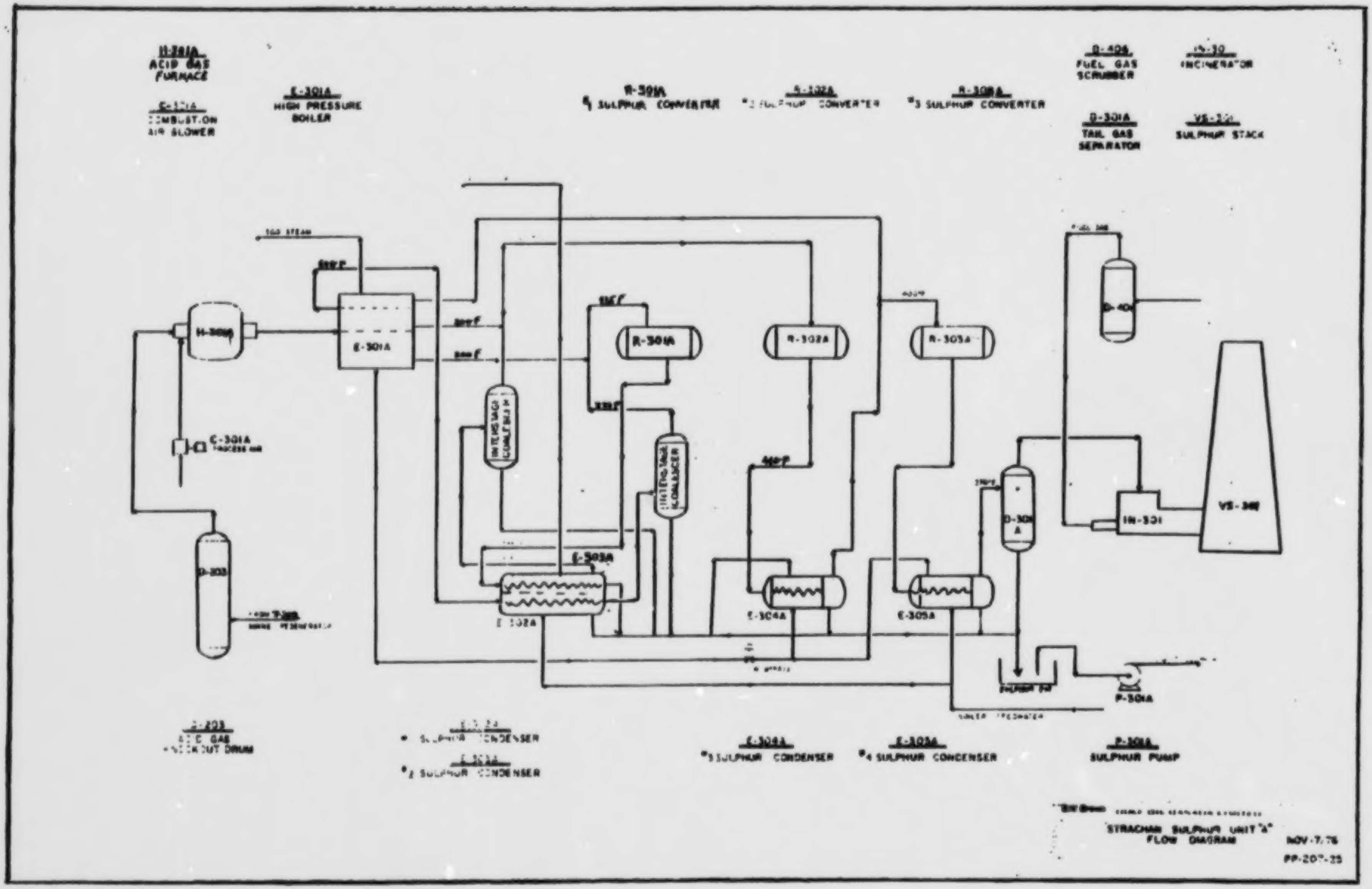

Figure 2.12 Strachan Sulfur Unit "A" Flow Diagram

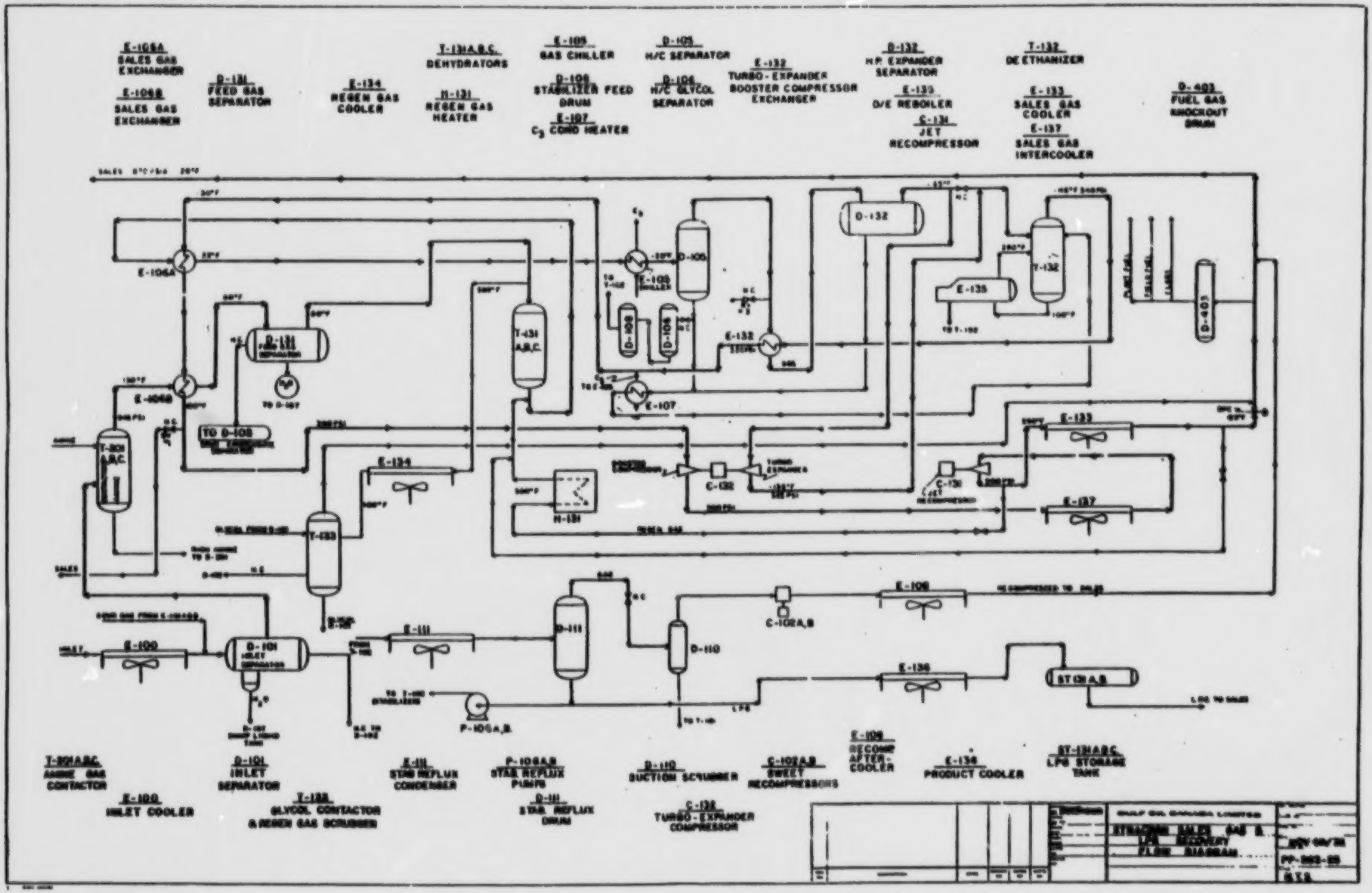

Figure 2.13 Strachan Sales Gas and LPG Recovery Flow Diagram

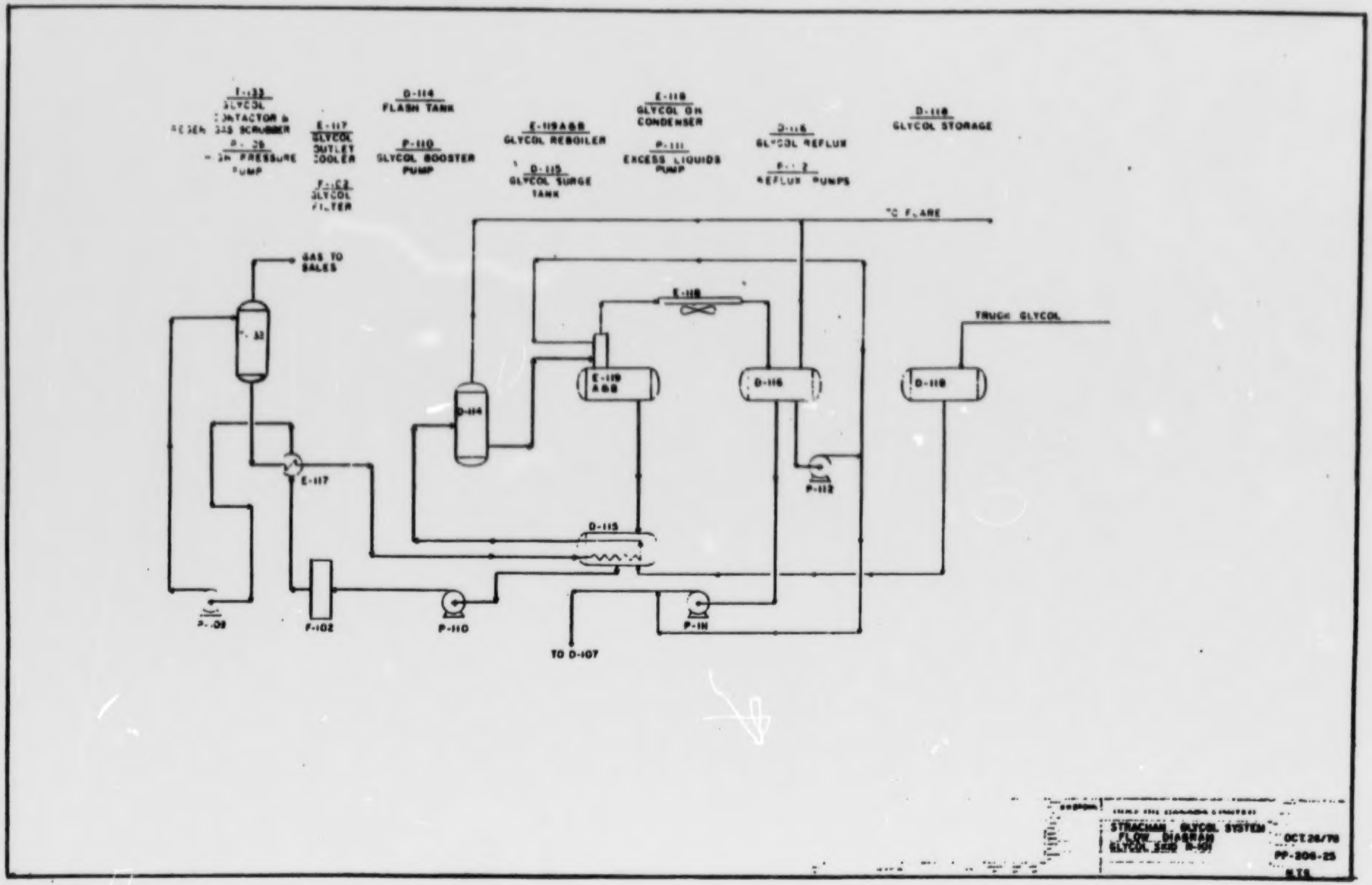

Figure 2.14 Strachan Glycol System Flow Diagram

Regeneration of exhausted Dehydrators (3) is accomplished by a reverse flow of hot gases of sales gas quality The regeneration gas, heated to 550°F in the Regeneration Gas Heater (17), strips adsorbed water and hydrocarbons from the Dehydrator (3) packing. Water and hydrocarbon removal from the regeneration gas is accomplished in the Glycol Contactor and Regeneration Gas Scrubber (18) by means of intimate contact with glycol which produces an overhead stream of sales gas quality. The spent glycol from the Glycol Contactor (18) is fed to the Glycol Regeneration System (19) where distillation effects a separation into a hydrocarbon stream that is flared, a water stream that is sent to well injection and fresh glycol that is recirculated to the Glycol Contactor and Regeneration Gas Scrubber (18).

2. Ram River Gas Plant (Canterra Energy Limited)

Canada's largest sulfur producer, the Canterra-Ram River Gas Plant, located 30 miles south west of Rocky Mountain House, Alberta operates in the shadows of the foothills. From the air this facility is readily identified by the large stack and extensive sulfur storage areas shown in Figure 2.15.

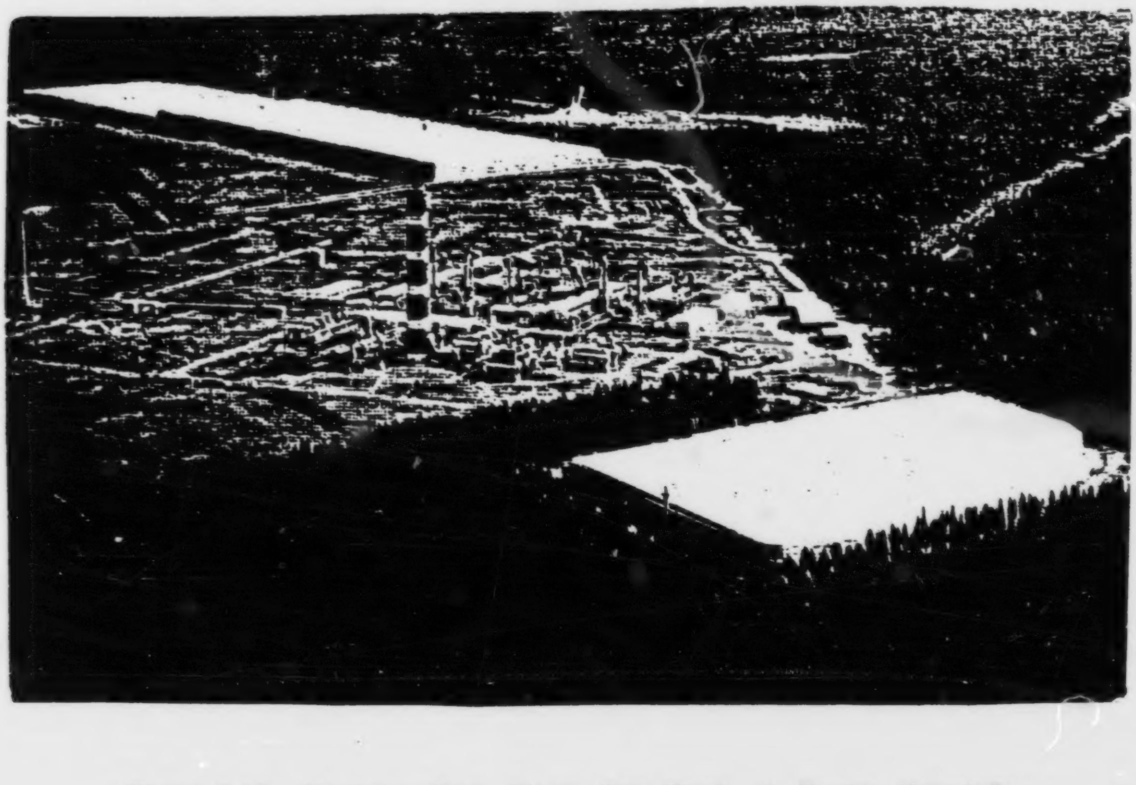

Figure 2.15 Canterra-Ram River Gas Plant at Rocky Mountain House, Alberta.

According to the block diagram illustrated in Figure 2.16 the Ram River Gas Plant processes sour gas from four fields. Their relative locations are shown in Figure 2.17.

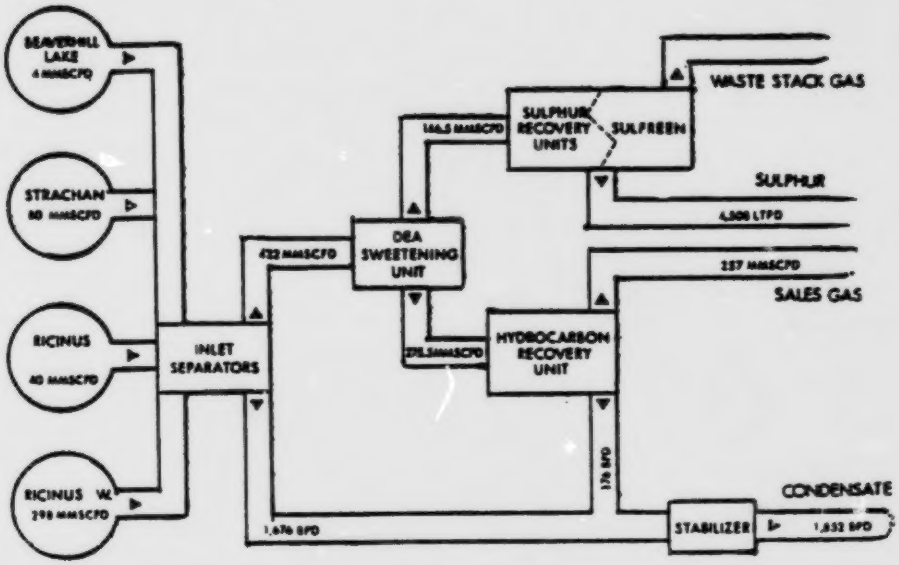

Figure 2.16 Block Diagram of Canterra-Ram River Gas Plant.

The six wells in the Ricinus West pool contribute a gas stream consisting of 35% hydrogen sulfide and 7% carbon dioxide. There are three wells in the Strachan field, and one well in the Ricinus and Beaverhill Lake fields that provide raw sour gas to the Ram River Gas Plant. Well pressures of 6,000 to 7,000 psia are sufficient to convey the raw gases to the plant where processing occurs at about 1,000 psia.

Although the raw gases from each field have different compositions and liquid contents, they all contain hydrogen sulfide, carbon dioxide, water, and liquid hydrocarbons. The Ricinus West D-3A and Beaverhill Lake A are considered as dry gas fields.

Figure 2.18 provides a schematic flow diagram of the Ram River Gas Plant. Incoming wet sour gas streams are first separated into a deliquefied sour gas, a liquid hydrocarbon fraction and water in the Inlet Separators (1, 2, 3) . The water is returned to the gas fields.

Deliquefied sour gases are processed in Absorbers (4) where acid gases [hydrogen sulfide (H_2S) and carbon dioxide (CO_2)] are removed, under high pressure, by an aqueous solution of diethanolamine (DEA). The sweet gas streams leaving the high

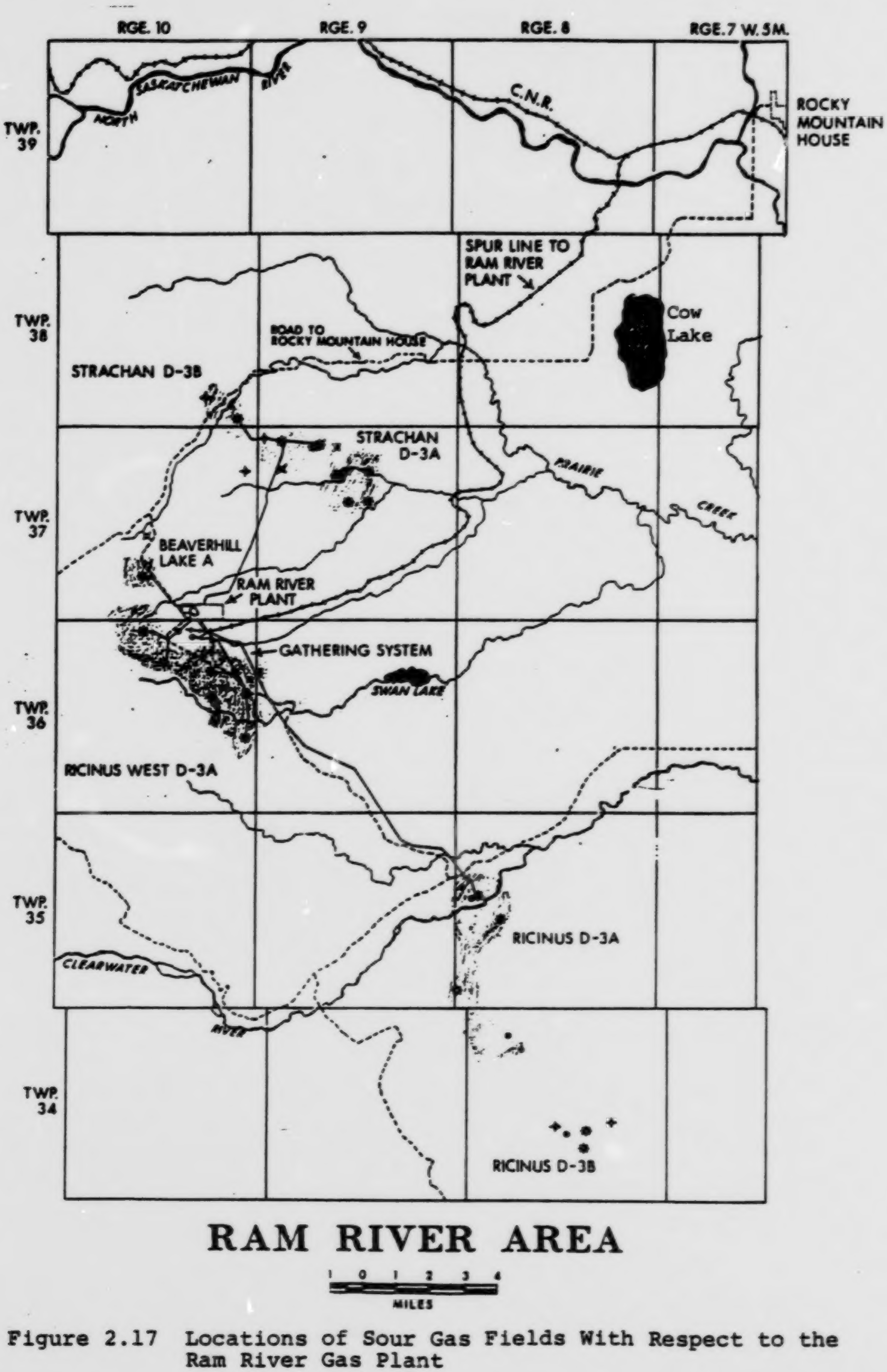

Figure 2.17 Locations of Sour Gas Fields With Respect to the Ram River Gas Plant

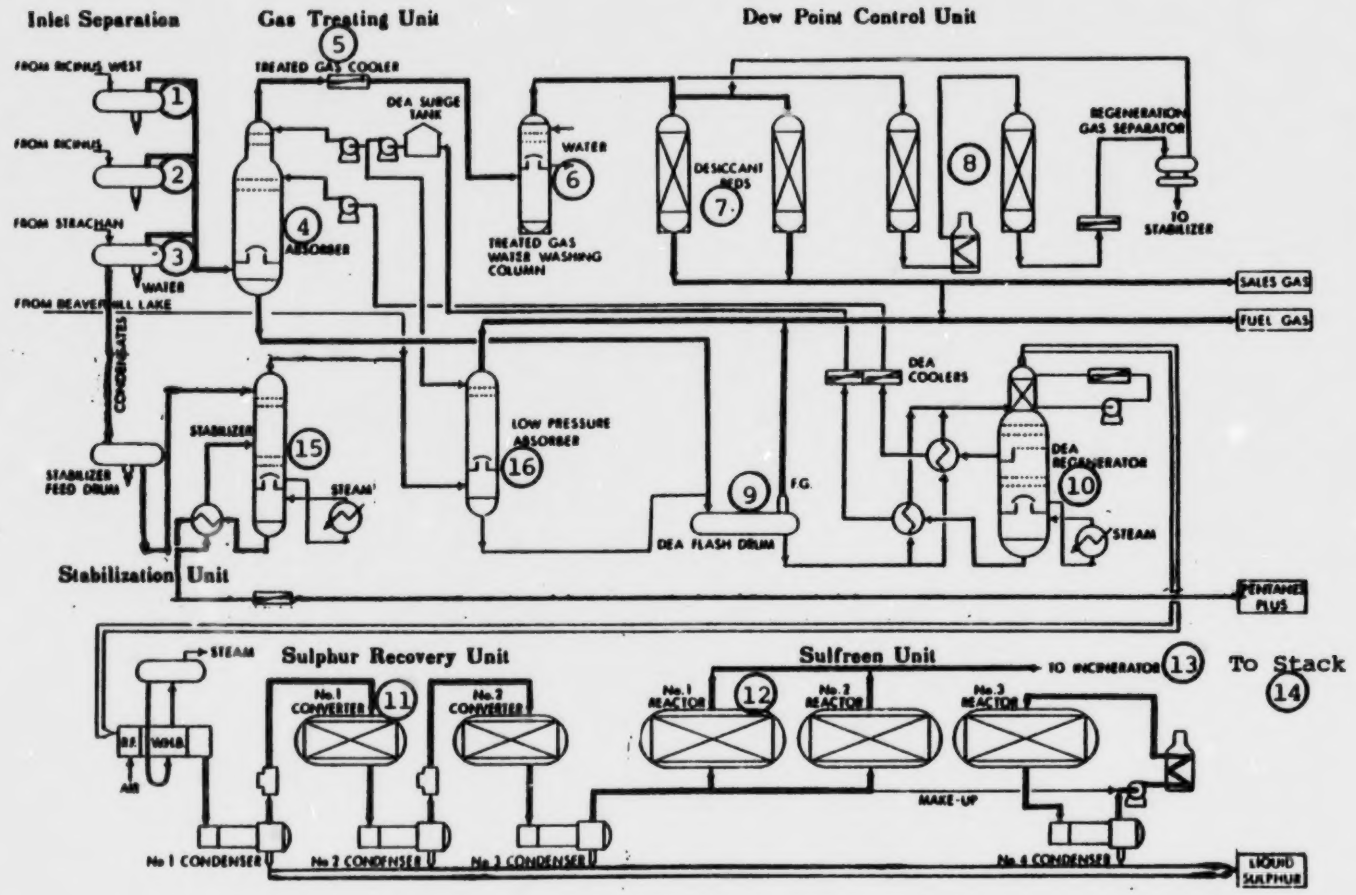

Figure 2.18 Schematic Flow Diagram of Canterra-Ram River Gas Plant

pressure Absorbers (4) are cooled (Treated Gas Cooler (5)) and cleaned in Water Wash Columns (6). Excess moisture and heavy hydrocarbons are removed by passing the sweet moist gases through Desiccant Beds (7) in the Desiccant Dew Point Control system. The dry clean product is distributed through the pipeline system as sales gas. The Desiccant Beds (7) are regenerated by means of hot gases from the Regeneration System (8) that strip the accumulated water and heavy hydrocarbons for further recovery of the hydrocarbon fraction.

The spent diethanolamine (DEA) solution leaving the high pressure Absorbers (4) is sent to the Low Pressure Regenerators (10) by way of the DEA Flash Drums (9) where volatile Fuel Gas components are removed by flashing. The DEA Regenerators (10) are distillation columns that strip the acid gases (H_2S and CO_2) for processing in the Sulfur Recovery (11) and Sulfreen (12) units. Regenerated diethanolamine (DEA) is pumped back to the high pressure Absorbers (4) for re-use.

The Sulfur Recovery System (11) consists of four Claus Convertors where approximately one third of the hydrogen sulfide (H_2S) in the acid gas streams leaving the DEA Regenerators (10) is burned with air to form water and sulfur dioxide (SO_2) according to the reaction

$$H_2S_g + 1\ 1/2\ O_{2g} \longrightarrow H_2O_g + SO_{2g}$$

The remainder of the incoming hydrogen sulfide (H_2S) is allowed to react with the generated sulfur dioxide (SO_2) to produce elemental sulfur by way of the reaction

$$2H_2S_g + SO_{2g} \longrightarrow 3S_l + 2H_2O_l$$

Residual amounts of hydrogen sulfide (H_2S) in the tail gases leaving the Claus Converters (11) are removed in the Sulfreen Reactors (12) to provide a better than 98% recovery of elemental sulfur.

To ensure that essentially no hydrogen sulfide (H_2S) escapes to the atmosphere the last traces of this gas are eliminated in the high temperature Incinerator (13) before the process gas stream is exhausted through the 300 foot high Incinerator Stack (14) shown in Figure 2.15.

The sour condensates, separated from the incoming natural sour gases in the Inlet Separators (1, 2, 3), are sent for distillation in the Stabilizer (15). Here the heavy pentane plus fraction is removed as a bottoms product that is pumped into a pipeline distribution system. The lower boiling overhead materials are treated in a low pressure diethanolamine (DEA) Absorber (16) where acid gases (H_2S and CO_2) are removed by DEA that releases them in the DEA Regenerators (10).

The gas stream leaving the low pressure Absorber (16) represents fuel gas that is used as fuel in the Incinerators (13).

3. Jumping Pound Gas Plant (Shell Canada Limited)

The operation of the Jumping Pound Gas Plant shown in Figure 2.19 can be discussed in terms of the simplified flow schematic illustrated in Figure 2.20.

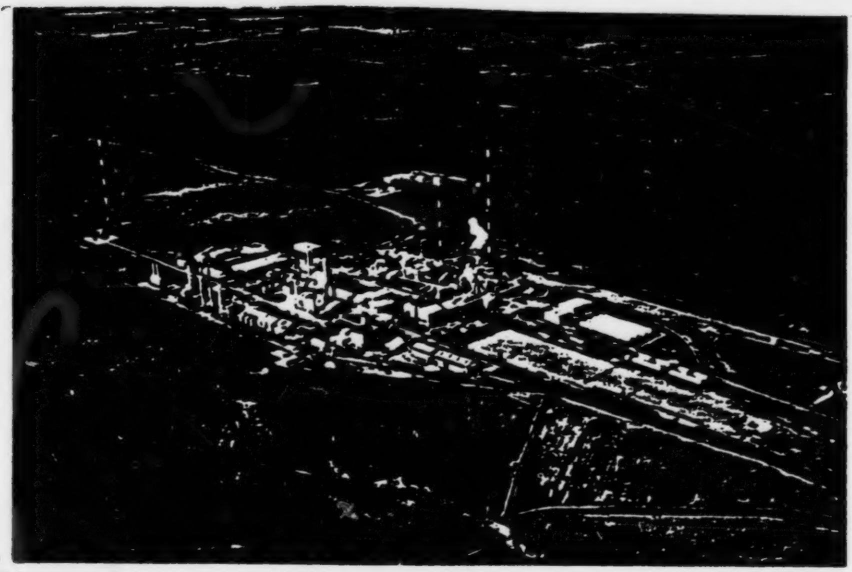

Figure 2.19 Shell-Jumping Pound Gas Plant at Cochrane, Alberta.

The Jumping Pound Gas Plant processes raw gas from some 29 wells in the Jumping Pound, Jumping Pound West and Sarcee fields. Water and liquid condensate (natural gasoline) are removed from the raw sour gases in the inlet separators (#1 and #2).

Because of declining field pressures, the deliquefied Jumping Pound and Sarcee field sour gas stream must be compressed to the operating pressures of the Amine Units (3 and 4) where hydrogen sulfide (H_2S) and carbon dioxide (CO_2) are removed. The sweet gases leaving the Amine Units (3 and 4) are fed to either the Absorption Unit (5) or the Refrigeration Unit (6) where residual heavier hydrocarbon components are separated from the lower molecular weight gas streams. Part of the wet low molecular weight sweet gas from the Absorption Unit (5) is dried in the Dehydration Unit (7) to meet sales gas moisture specifications. The remainder is sent to the Liquefiable Petroleum Gases (LPG) Unit (8) where propane, butane, and residual heavier hydrocarbons (pentanes plus fraction) are stripped from the gas stream that ultimately becomes sales gas.

Low molecular weight gases separated in the Refrigeration Unit (6) can leave the plant as sales gas or be sent to the LPG Unit (8) for removal of propane, butane, and a pentane plus fraction. The heavier molecular weight fraction from the Refrigeration Unit (6) is fed directly to the LPG Unit (8) where propane, butane and residual heavier hydrocarbons (pentanes plus) are stripped from the gas stream before it is sold.

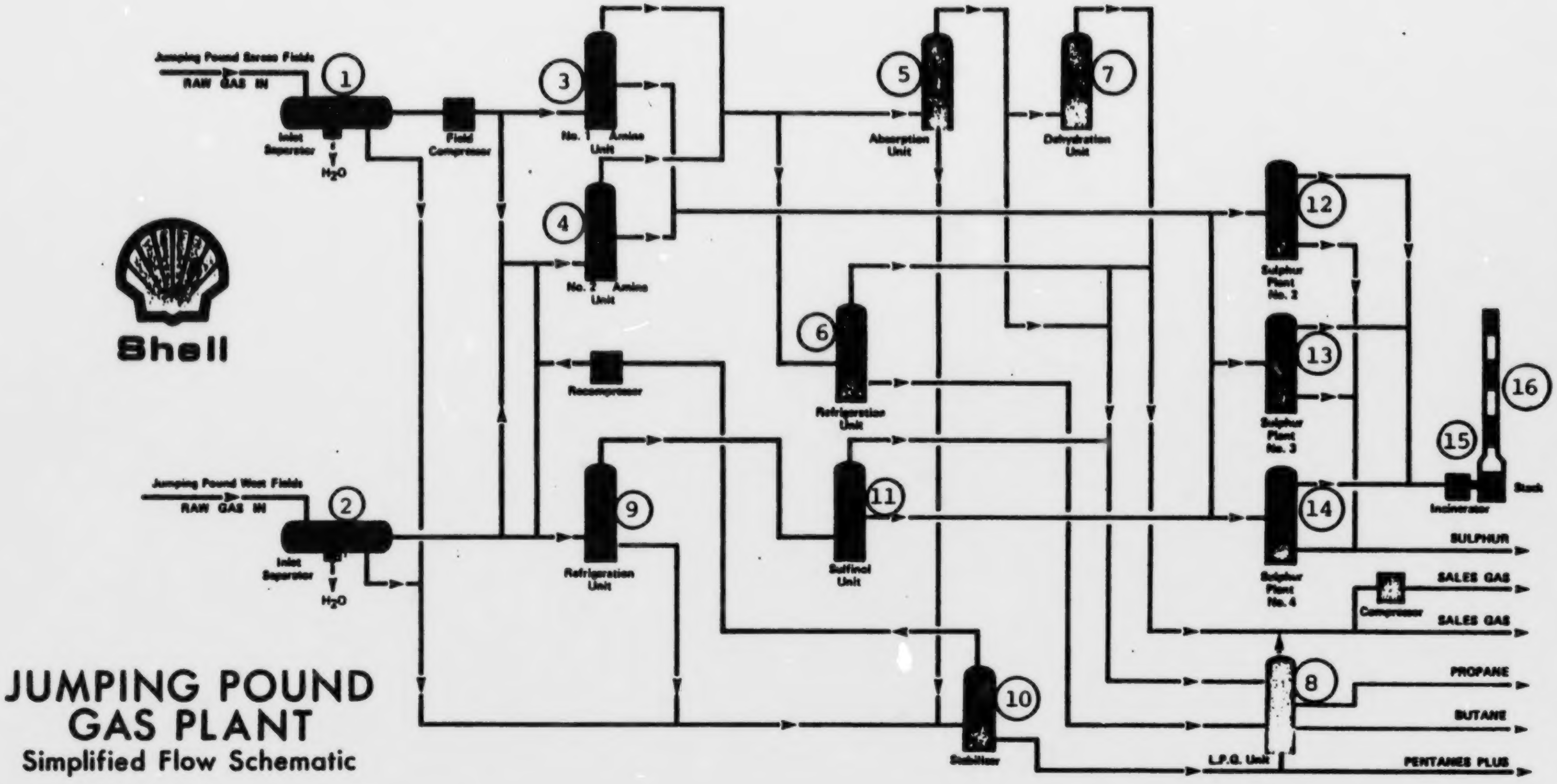

Figure 2.20 Simplified Flow Schematic of Jumping Pound Gas Plant

The deliquefied sour gas stream from the Jumping Pound West fields is cooled in a Refrigeration Unit (9) where the heavier molecular weight hydrocarbon fraction is removed as sour condensate and sent to the Stabilizer (10) along with the sour condensate from the Inlet Separators (1 and 2) and the gasoline leaving Absorption Unit (5).

The low molecular weight sour gas stream from the Refrigeration Unit (9) is sweetened in the Sulfinol Unit (11) through removal of hydrogen sulfide (H_2S) and carbon dioxide (CO_2). The sweetening process involves contacting the sour gas stream with a proprietary Shell developed aqueous alkaline solution known in the trade as Sulfinol. The sweet gas from the Sulfinol Unit (11) is fed to the LPG Unit (8) for removal of propane, butane, and pentanes plus before it is disposed of as sales gas.

The residual hydrogen sulfide (H_2S) and lighter hydrocarbons in the sour condensate and gasoline streams are separated from the stable pentanes plus fraction in the Stabilizer (10). The recovered hydrogen sulfide (H_2S) and lighter hydrocarbons are compressed and recycled to the Amine (4) or Refrigeration (9) plus Sulfinol (11) Units for reprocessing.

The acid gases consisting of hydrogen sulfide (H_2S) and carbon dioxide (CO_2) which were separated from the raw sour gases in the Amine Units (3 and 4) or the Sulfinol Unit (11) are fed to the three sulfur plants (12, 13, and 14). The Claus Units (12, 13, and 14) are designed to convert 95% of the hydrogen sulfide (H_2S) to liquid sulfur by first reacting approximately one third of the hydrogen sulfide (H_2S) according to the process

$$H_2S_g + 1\ 1/2\ O_{2g} \longrightarrow H_2\ O_g + SO_{2g}$$

The remainder of the hydrogen sulfide (H_2S) is reacted with the generated sulfur dioxide (SO_2) to produce elemental sulfur according to the scheme

$$2\ H_2S_g + SO_{2g} \longrightarrow 2\ H_2O_l + 3\ S_l$$

The liquid sulfur can be loaded directly into tank trucks, railroad tank cars, or poured to form field storage blocks.

Any unreacted hydrogen sulfide (H_2S) that escapes from the Claus sulfur converters (12, 13, and 14) is incinerated to sulfur dioxide (SO_2) in the Incinerator (15) before the gas stream is exhausted to the atmosphere through a 335 foot (102 meter) Stack (16).

III. SAMPLE RECOVERY

Quantitative recovery of the samples from all parts of the train required a rigorous and meticulous procedure which took 3 to 4 hours to complete.

A. INTRODUCTION

Upon completion of a test the main power switch and both flow control valves were closed. After the probe was rotated so that the nozzle inlet faced downstream, the probe assembly was pushed into the stack so that the impinger case was accessible from the sampling platform. Then the oven door was opened. The glassware was allowed to cool and the glass probe liner was disconnected from the cyclone-bypass. After the probe glass ball socket and the cyclone-bypass ground glass joint were sealed the complete impinger case was removed from the traversing rail and safely positioned on the sampling platform.

The probe assembly was then slowly removed from the port while maintaining cooling air flow through the probe jacket. When the probe could be safely handled with high temperature heat resistant gloves it was removed from the port. The nozzle tip was sealed and protective end caps were placed over the nozzle-Pitot-RTD and the ground glass ball socket to prevent physical damage to the exposed parts. Cooling air flow was maintained until the probe could be safely handled with bare hands.

While the probe was cooling the impinger assembly was sealed and lowered to ground level for sample recovery in the laboratory. The probe cleanup which took place at the sampling platform level, was facilitated by the use of a custom built support system which rode on the traversing rail. A detailed step-by-step cleanup procedure follows for the nozzle-probe, filter, impingers in the ice-water bath and impingers in the dry ice-acetone bath. Figure 3.1 details sample recovery from the component parts of the train.

B. NOZZLE-PROBE

For cleanup purposes, the protective caps were removed from both ends of the probe assembly and the sealed nozzle exterior wiped with paper towels.

1. Nozzle

After removing the nozzle and sealing the end of the glass liner, the nozzle was rinsed with 6M nitric acid (see Appendix II) from a polyethylene wash bottle, into a labelled 500 mL sample bottle A1.

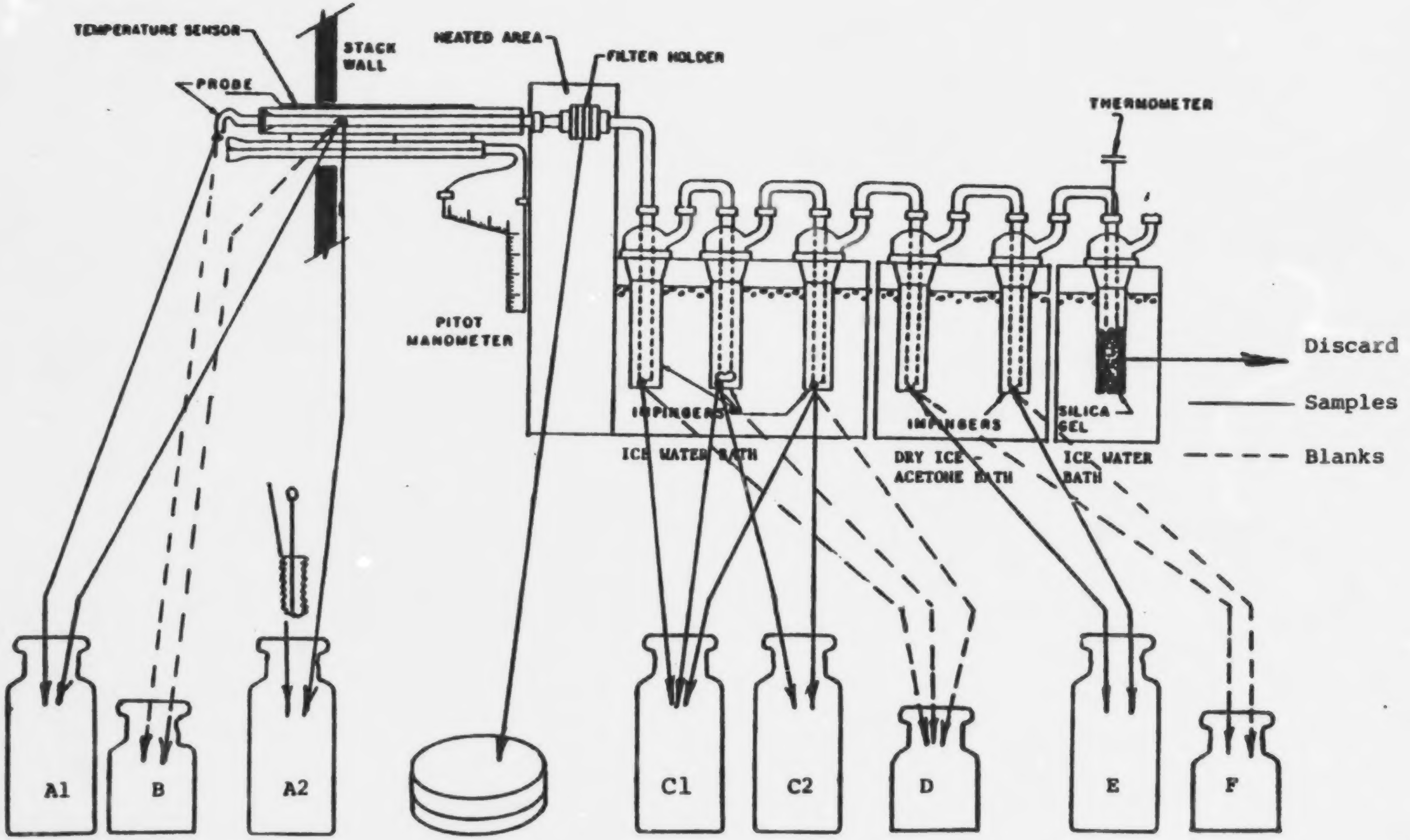

Figure - 3.1 Sample Recovery Procedure

The interior of the nozzle was vigorously scrubbed with a nylon bristle brush mounted on a stainless steel wire handle. The rinsing-brushing operations continued until the washings showed no visible particles. Approximately 150 mL more of 6M $HN0_3$ were used in this step. All washings were collected in sample bottle A1.

Finally, the nozzle was rinsed with deionized distilled water which was discarded. The clean nozzle was placed into a protective polyethylene bag for use in the next test.

All sample bottles were new and constructed of borosilicate glass with Teflon seals in the screw type caps. Prior to use, the new sample bottles were cleaned in a glass washer with Alconox water solution then rinsed with 6-M nitric acid ($HN0_3$) and finally deionized distilled water (see Appendix I). Immediately prior to field use, the bottles were rinsed with 0.1M $HN0_3$.

2. Probe

The probe assembly was placed in the support system and the exterior of both liner ends wiped with paper towels. The probe liner was cleaned by first tilting and rotating the probe while squirting approximately 350 mL of 6M $HN0_3$ into the upper end. The nitric acid wash was collected in labelled container A1.

Next the nylon probe brush, with stainless steel wire handles and extensions, was used to vigorously scour the liner interior. Another 350 mL of 6M nitric acid were passed through the tilted probe liner, while rotating, and collected into a second container, A2. This procedure was repeated until the washings showed no visible particles. Then the liner was visually inspected to confirm that it was clean and minimal rinse acid was held up in the liner. The probe brush was rinsed into container, A2 and both sample bottles, A1 and A2 were marked for liquid level and carefully stored.

The liner was rinsed with deionized distilled water which was discarded, both ends sealed and the protected covers replaced.

3. Nozzle-Probe Blanks

Before the next test, both the nozzle and probe liner were rinsed with 0.1 M $HN0_3$ which was collected in labelled container B (100 mL). This blank constituted an additional test for gross contamination which might occur during storage and/or shipment between tests.

The container liquid level was marked and the blank stored for subsequent trace element analysis. The nozzle and probe were rinsed with distilled water and then put together for the test to follow.

C. FILTER

In the laboratory the filter holder was carefully removed from the oven and separated from the cyclone bypass.

1. Filter Removal

The quartz filter was carefully removed from the filter holder using a pair of nonserrated nylon tipped tweezers and a Teflon coated razor blade to lift the filter from the gasket.

The filter, which had been tared to the nearest ±0.1 mg at constant weight in a 50 percent relative humidity atmosphere, was placed into a labelled disposable Petri dish made of polystyrene.

Next the gasket was carefully scraped with the Teflon coated razor to remove any filter matter adhering to the surface. This material was added to the Petri dish, which was sealed, then carefully stored for later trace element analysis and final weighing at 50% relative humidity.

2. Cyclone-Bypass and Filter Front End

The silicone grease was removed from the ground glass joints and the cyclone bypass rinsed with 6 M HNO_3 into container A2. The front half of the borosilicate glass filter holder was similarly cleaned into the same container. After brushing and rinsing until clean, the final liquid level was noted on container A2.

The cyclone-bypass and filter holder were then rinsed with 0.1 M HNO_3 and deionized distilled water to ready them for reassembly.

D. IMPINGER TRAIN

The two cold trap impingers (dry ice-acetone bath) were separated from the four impingers in the ice-water bath by removing the glass connections which were placed on disposable polyethylene sheets. The high temperature silicon grease* was then removed from the ground glass joints on every piece of connecting glassware and impinger using disposable paper towels.

1. Moisture Determination

Water was wiped from the outside walls of each impinger with absorbent paper. Then all six impingers were weighed to the nearest ±0.1 gm on a trip balance to allow stack gas moisture determinations following the condensation method (AERM-3).(11) The Drierite contained in impinger 6 was discarded.

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*Dow Corning High Vacuum Grease.

2. Impingers 1, 2 and 3 at Ice-Water Bath Temperature

The contents of impingers 1, 2 and 3 were emptied into labelled container C1 (and C2 if required). Then 20-30 mL of 6M HNO_3 from a polyethylene wash bottle was used to rinse each impinger. The rinses were collected into container C1 or a second container C2.

After brushing the inlet and outlet passages of each impinger, they were rinsed again with 6M HNO_3. Approximately 25-mL of 6M HNO_3 were added to each impinger, which was shaken vigorously for 2-3 minutes. The washes were emptied into container C2. These procedures were continued until the surfaces were visibly clean. Normally the total rinse volumes, initial impinger acid charges, and condensed water vapor required two 500 mL sample bottles.

3. Blank - Impingers 1, 2, and 3

Before the next test approximately 25 mL of 0.1 M HNO_3 were added to each impinger which was vigorously shaken for 2-3 minutes. The washes were poured into labelled container D to constitute a blank for the next test. This additional step provided a check on possible gross contamination during storage and/or shipment between tests.

Each impinger was then flushed with deionized distilled water which was discarded.

Impingers 1 and 2 had approximately 100 mL of 6M HNO_3 added to the marked level for use in the next test.

After taring, the water-bath impingers (1, 2, and 3) were then assembled for the next test.

4. Impingers 4 and 5 at Dry Ice-Acetone Bath Temperature

The contents of impingers 4 and 5 were emptied into labelled container E. Each impinger was rinsed with 20-30 mL of 6M HNO_3 with the rinses being added to the sample bottle. Inlet and outlet passages were brushed and a final wash with 6M HNO_3 was completed in the same manner as for impingers 1, 2 and 3.

5. Blank-Impingers 4 and 5

At the start of the next test approximately 25 mL of 0.1M HNO_3 were added to each impinger which was vigorously shaken for 2-3 minutes. The washes were poured into labelled container F which constituted a blank for the next test. After flushing with deionized distilled water, which was discarded, impingers 4 and 5 were weighed and assembled.

6. Connecting Glassware

The glassware used to connect the impinger train was removed from the disposable polyethylene sheets mentioned earlier and any material adhering to the walls was rinsed with 6M HNO_3 into appropriate containers. After brushing the walls, the connectors were again rinsed with 6M HNO_3. The rinses from glassware connecting impingers 1, 2 and 3 were added to bottle C1 or C2 and the rinses from impingers 4 and 5 connectors were added to bottle E. Final deionized distilled water rinses readied the connectors for the subsequent test.

IV. ANALYTICAL PROCEDURES

Literature reviews,(13-16) discussions with chief chemists at industrial,(20) academic(26) and regulatory organizations(19) as well as personal experiences suggested that atomic absorption spectrometry (AAS) offered the most viable approach to the measurement of the 29 trace elements of concern to this investigation. Generally, atomic absorption is relatively interference free, however, high concentrations of dissolved salts can produce interference by scattering, particularly when analyses are carried out at UV wavelengths. Although atomic absorption is normally not a sensitive technique for arsenic, selenium and mercury determinations, modification of the standard procedures can lower detection limits by 2 orders of magnitude. For example, furnace techniques can be used to improve analyses for selenium, arsenic and vanadium. The cold vapour procedure has been reported to be a reliable method of determining trace amounts of mercury(12, 27-28).

To ensure complete dissolution of all but the most inert metallic species that were collected as particulate matter, it would be desirable to use a mixture of nitric and hydrochloric acids for preparation of the solutions to be subjected to atomic absorption spectrometry. However, the use of hydrochloric acid must be limited to prevent significant losses of the volatile halides of arsenic, selenium and vanadium during the evaporation of excess acid. Consequently, all sample preparation was done in parallel to provide one group of metals in nitric acid and another in hydrochloric acid. Table 4.1 details the selection of acids for the dissolution of the metals pertinent to this investigation. Also provided are the analytical parameters for atomic absorption analyses.

A. DEVELOPMENT

1. Pre-Test Program

Since it was not possible to predict the amount of any element that would be collected in any component of the sampling train, analytical procedures were developed for trace level determinations. Consequently, it was important to quantify the contribution of any metallic species from the distilled water, nitric acid and filters used during sample collection and/or recovery as well as the stainless steel liner that was proposed for the larger incinerator stacks.

All preliminary analyses of distilled water, nitric acid, filters and probe and impinger washings were carried out by Analytic and Biological Laboratories, Inc.(29) with an Inductively Coupled Argon Plasma (ICAP) Spectrometer manufactured by Applied Research Laboratories of Sunland, California. The instrument specifications are detailed in Appendix III.

Element		Analytical Wavelength	Detection Limit (mg/L)	Sensitivity (mg/L)	Flame Type	Optimum Concentration Range (mg/L)	Acid Prep	Comments
Ag	Silver	3281	0.05	0.03	A-Ac	0.1-2.0	HNO_3	
Al	Aluminum	3093	1.0	0.4	N-Ac	5.0-100	HCl	Add 2000 ppm K
As	Arsenic	1937	0.005	0.005	furnace	0.005-0.05	HNO_3	
B	Boron	2497	10	9	N-AC	50-500	HNO_3	
Be	Beryllium	2349	0.02	0.01	N-AC	0.1-2.0	HCl	Add 5% 8-hydroxyquinoline
Cd	Cadmium	2288	0.02	0.01	A-AC	0.1-2.0	HNO_3	
Co	Cobalt	2407	0.2	0.05	A-AC	0.5-10	HCl	
Cu	Copper	3247	0.1	0.03	A-AC	0.5-10	HNO_3	
Cr	Chromium	3579	0.2	0.06	N-AC	0.5-10	HNO_3	
Fe	Iron	2483	0.1	0.04	A-AC	0.5-10	HNO_3	
Ga	Gallium	2874	2.0	1.5	N-AC	5-100	HNO_3	Add 2000 ppm K
Ge	Germanium	2651	2.0	1.0	N-AC	5-100	HNO_3	
Hg	Mercury	2537	0.01	0.01	Cold vapor	0.01-0.1	Special prep	
In	Indium	3040	1.0	0.2	N-AC	5.0-100	HNO_3	Add 2000 ppm K
Li	Lithium	6708	0.05	0.02	N-AC	0.1-2.0	HCl	Add 2000 ppm K
Mn	Manganese	2795	0.05	0.02	A-AC	0.1-2.0	HNO_3	
Mo	Molybdenum	3133	0.5	0.2	N-AC	1.0-20	HNO_3	Add 1000 ppm Al
Ni	Nickel	2320	0.2	0.06	A-AC	0.5-10	HNO_3	
Pb	Lead	2170	0.2	0.1	A-AC	0.5-10	HNO_3	
Sb	Antimony	2176	0.4	0.2	A-AC	1.0-20	HCl	
Sc	Scandium	3912	0.5	0.1	N-AC	2.0-50	HCl	Add 2000 ppm K
Se	Selenium	1960	0.01	0.01	Furnace	0.01-0.05	HNO_3	
Sn	Tin	2355	1.0	1.0	N-AC	5.0-100	HCl	
Sr	Strontium	4607	0.05	0.1	N-AC	0.1-2.0	HNO_3	Run by emission add 2000 ppm K
Te	Tellurium	2143	0.5	0.2	A-AC	1.0-2.0	HNO_3	
Ti	Titanium	3643	1.0	1.0	N-AC	10-200	HCl	Add 2000 ppm Al
Tl	Thallium	2768	0.5	0.1	A-AC	1.0-20	HNO_3	
V	Vanadium	3185	0.02	0.01	Furnace	0.05-0.5	HNO_3	
Zn	Zinc	2138	0.03	0.01	A-AC	0.1-2.0	HCl	

Table 4.1 Summary of Analytical Parameters for Atomic Absorption Analysis

Distilled water from the University of Calgary and the University of Alberta as well as demineralized water prepared by the Energy Resources Conservation Board Laboratory in Edmonton, Alberta were analyzed for trace metal contents.

Blank samples of Baker Instra-Analyzed nitric acid were subjected to ICAP analysis during two separate pre-testing programs involving determination of background levels of metals on fibre glass and micro-quartz filters and an estimation of the leaching effect when stainless steel probe liners are washed with 6M nitric acid.

Conventional 125 mm borosilicate glass fibre and 125 mm quartz microfibre filters obtained from Whatman Laboratory Products, Inc. Paper Division(30) were subjected to the proposed nitric and hydrochloric acid leaching procedures. In addition, one sample of 8 x 10 inch quartz microfibre hi-vol filter was extracted with nitric and hydrochloric acids. The resultant solutions were examined with the ICAP spectrometer for all 29 elements of interest to this study.

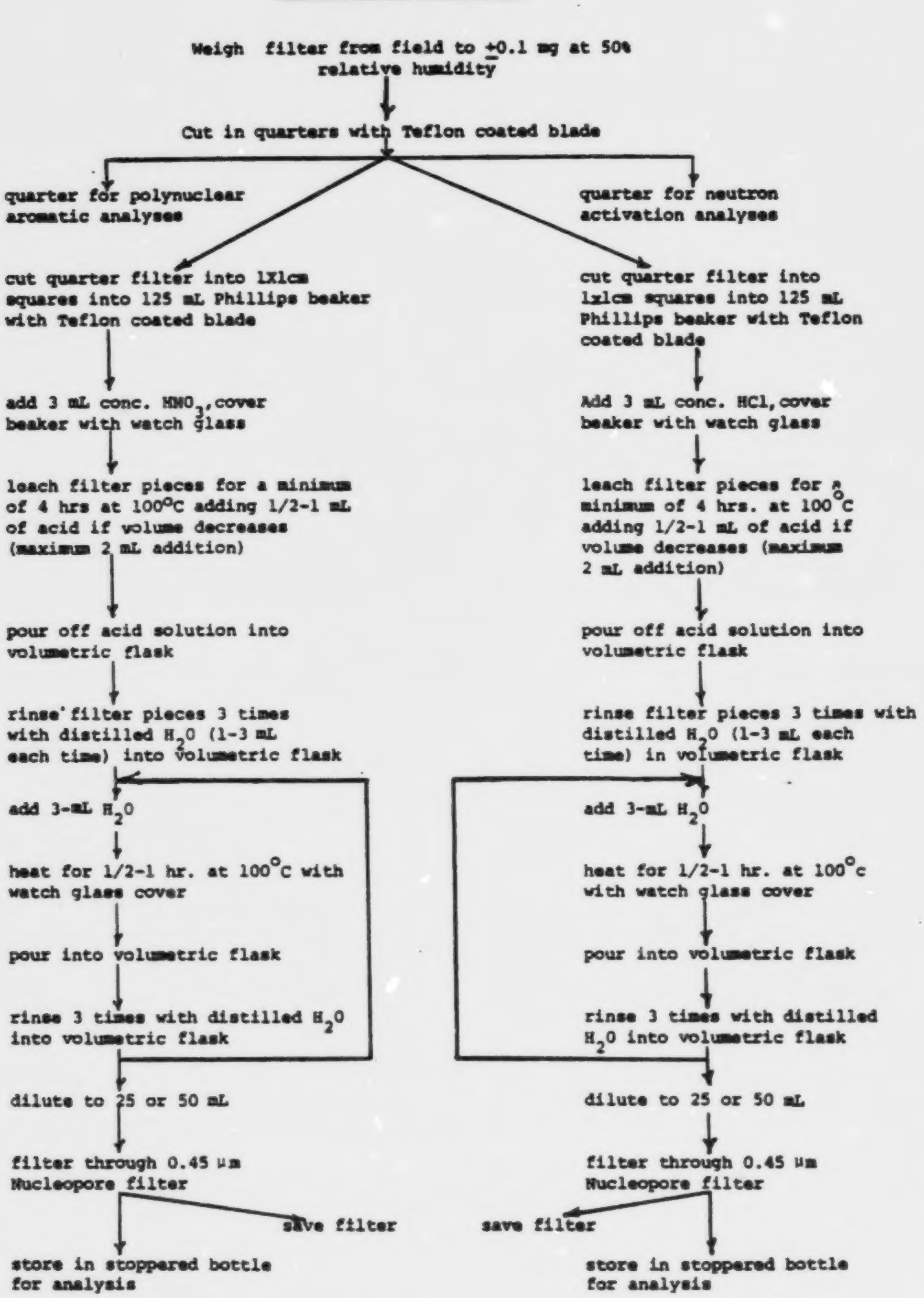
After construction of the 17 foot probe had been completed, the internal stainless steel liner, the three impingers, the two cold trap impingers and all connecting glassware comprising the stack sampling train were washed with volumes of 6M nitric acid solutions that matched the amounts projected for onsite sample recovery after each test. All of these washings were subjected to ICAP spectrometry.

2. Preliminary Field Testing at Canterra - Ram River Plant

The samples collected during the preliminary testing of the Canterra - Ram River plant on August 25, 1982 were used to finalize the analytical procedures for all samples acquired during the trace element emission study. These source samples were selected since the filter was coated with a dark deposit and the impinger solutions were straw colored. In order to identify the materials on the filter and in the solutions, specimens were submitted for atomic-absorption (AA), neutron activation (NA) and high performance liquid chromatography (HPLC) analyses.

Figure 4.1 illustrates the steps required to produce solutions for atomic absorption from the filter catch obtained during the preliminary test at Ram River.

The filter was quartered to provide a specimen for polynuclear aromatic analysis by HPLC to establish the composition of the blackish material covering the filter surface. After extraction with methylene chloride, a section was cut from the approximate centre of the filter quarter for mounting in a specimen holder to facilitate coating with carbon in a vacuum evaporator. Another section from the white edge of the filter quarter was prepared similarly as a blank for comparison. Both specimens were subjected to Scanning Electron Microscopy/Energy-Dispersive Spectrometry (SEM/EDS).


Preliminary Test Filters
Weigh filter from field to ±0.1 mg at 50% relative humidity
Cut in quarters with Teflon coated blade
quarter for polynuclear aromatic analyses
quarter for neutron activation analyses
cut quarter filter into 1X1cm squares into 125 mL Phillips beaker with Teflon coated blade
cut quarter filter into 1x1cm squares into 125 mL Phillips beaker with Teflon coated blade
add 3 mL conc. HNO3, cover beaker with watch glass
Add 3 mL conc. HCl, cover beaker with watch glass
leach filter pieces for a minimum of 4 hrs at 100°C adding 1/2-1 mL of acid if volume decreases (maximum 2 mL addition)
leach filter pieces for a minimum of 4 hrs. at 100°C adding 1/2-1 mL of acid if volume decreases (maximum 2 mL addition)
pour off acid solution into volumetric flask
pour off acid solution into volumetric flask
rinse filter pieces 3 times with distilled H2O (1-3 mL each time) into volumetric flask
rinse filter pieces 3 times with distilled H2O (1-3 mL each time) in volumetric flask
add 3-mL H2O
add 3-mL H2O
heat for 1/2-1 hr. at 100°C with watch glass cover
heat for 1/2-1 hr. at 100°C with watch glass cover
pour into volumetric flask
pour into volumetric flask
rinse 3 times with distilled H2O into volumetric flask
rinse 3 times with distilled H2O into volumetric flask
dilute to 25 or 50 mL
dilute to 25 or 50 mL
filter through 0.45 μm Nucleopore filter
filter through 0.45 μm Nucleopore filter
save filter
save filter
store in stoppered bottle for analysis
store in stoppered bottle for analysis

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.1 Preparation of Solutions From Preliminary Test Filter Catch at Ram River Gas Plant (Preliminary Digestion Procedure)

A second quarter was sent to the University of Toronto for an independent metal analysis by neutron activation techniques.

The preparation of solutions from the probe and nozzle wash and impinger contents and washes is depicted in Figure 4.2. In order to establish where significant amounts of material might be collected in the impinger train, the impingers were treated as units involving impinger 1, impingers 2 and 3, and impingers 4 and 5. Twenty or 30 millilitre aliquots were taken from each unit for the initial analyses.

The preparations of filter and solution blanks are illlustrated in Figure 4.3 and Figure 4.4, respectively.

Because the preliminary procedures failed to detect the presence of any of the 29 metal species, it became necessary to achieve as much concentration as possible before submitting the final samples to the atomic absorption techniques.

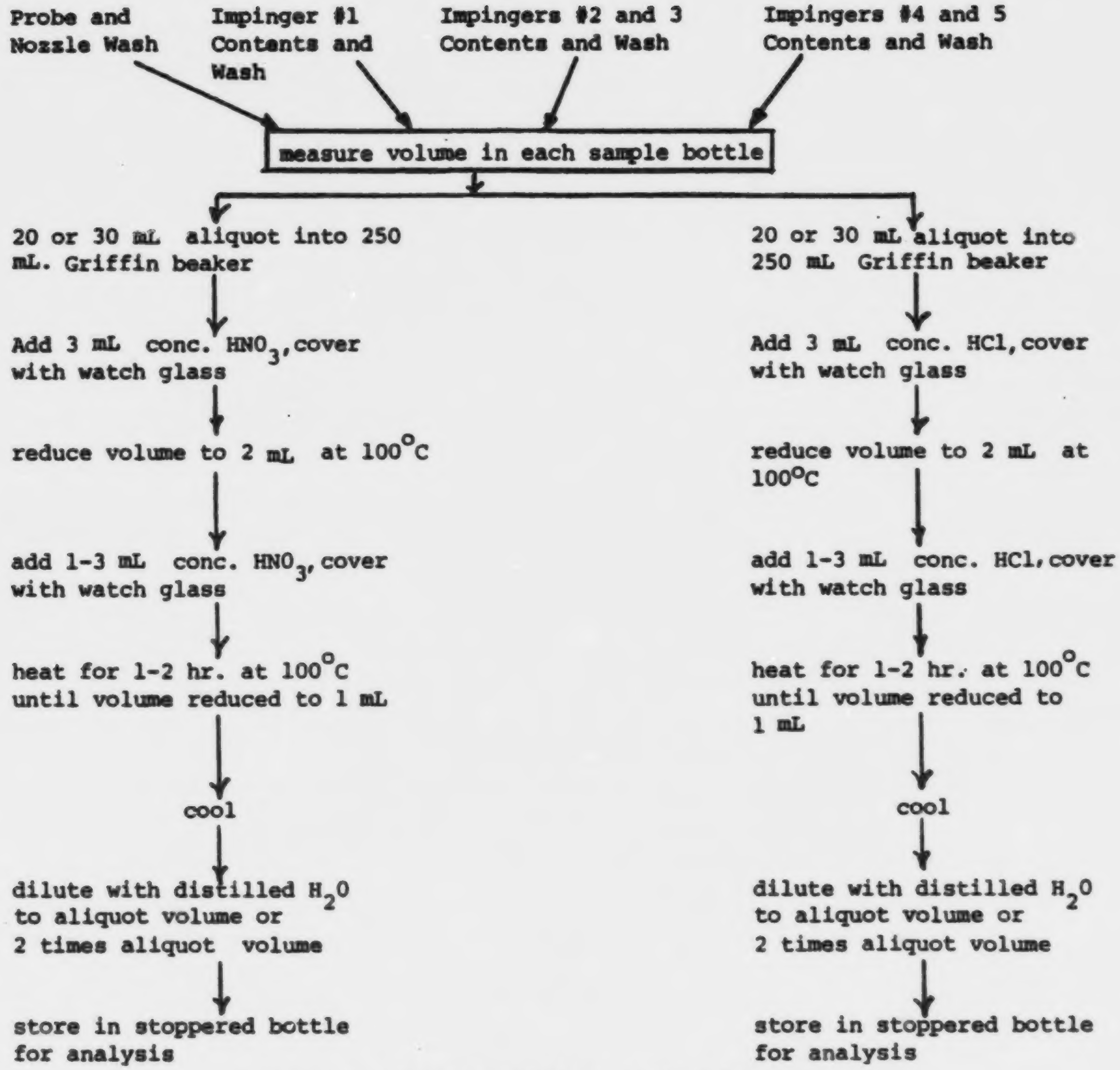
B. PLANT TESTS

As shown in Figure 4.5 the filters from all final tests were cut into halves to provide more concentrated HNO_3 and HCl solutions of the metals under investigation. All test liquid catches were treated according to the flowsheet illustrated in Figure 4.6. Impingers 1 , 2 and 3 were combined and the total volume was reduced to 25 mL by evaporation. Similarly the combined volume of impingers 4 and 5 was reduced to 25 mL by evaporation.

The preparation of filter and solution blanks is illustrated in Figure 4.7. Because of the potential for interferences and matrix effects to be created as a result of the complexity of the solutions being analyzed, it was essental to determine the recovery of each metal species by creating synthetic systems of known composition of each of the 29 elements under investigation. Clean filters and distilled water samples were spiked with appropriate volumes of the 1000 ppm AA standards according to the schemes illustrated in Table 4.2 and Table 4.3, respectively. The preparations of solutions from the filter and liquid recoveries are illustrated in Figures 4.8 and Figure 4.9, respectively.

C. ATOMIC ABSORPTION SPECTROMETRY

Atomic absorption analyses were carried out with an Instrumentation Laboratory Model IL 551 Video I double beam atomic absorption/atomic emission spectrophotometer with microcomputer, cathode-ray tube display. Flameless analyses were performed using a Varian Model 975 spectrophotometer equipped with a Varian temperature controlled furnace Model GTA95. The instruments were equipped to use air/acetylene, nitrous oxide/acetylene, or argon/hydrogen flames depending on the element being investigated. Table 4.1 summarizes the flame types for each element.


Probe and Nozzle Wash
Impinger #1 Contents and Wash
Impingers #2 and 3 Contents and Wash
Impingers #4 and 5 Contents and Wash
measure volume in each sample bottle
20 or 30 mL aliquot into 250 mL. Griffin beaker
Add 3 mL conc. HNO_3, cover with watch glass
reduce volume to 2 mL at 100°C
add 1-3 mL conc. HNO_3, cover with watch glass
heat for 1-2 hr. at 100°C until volume reduced to 1 mL
cool
dilute with distilled H_2O to aliquot volume or 2 times aliquot volume
store in stoppered bottle for analysis
20 or 30 mL aliquot into 250 mL Griffin beaker
Add 3 mL conc. HCl, cover with watch glass
reduce volume to 2 mL at 100°C
add 1-3 mL conc. HCl, cover with watch glass
heat for 1-2 hr. at 100°C until volume reduced to 1 mL
cool
dilute with distilled H_2O to aliquot volume or 2 times aliquot volume
store in stoppered bottle for analysis

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.2 Preparation of Solutions From Preliminary Test Liquid Catches at Ram River Gas Plant (Preliminary Digestion Procedure)

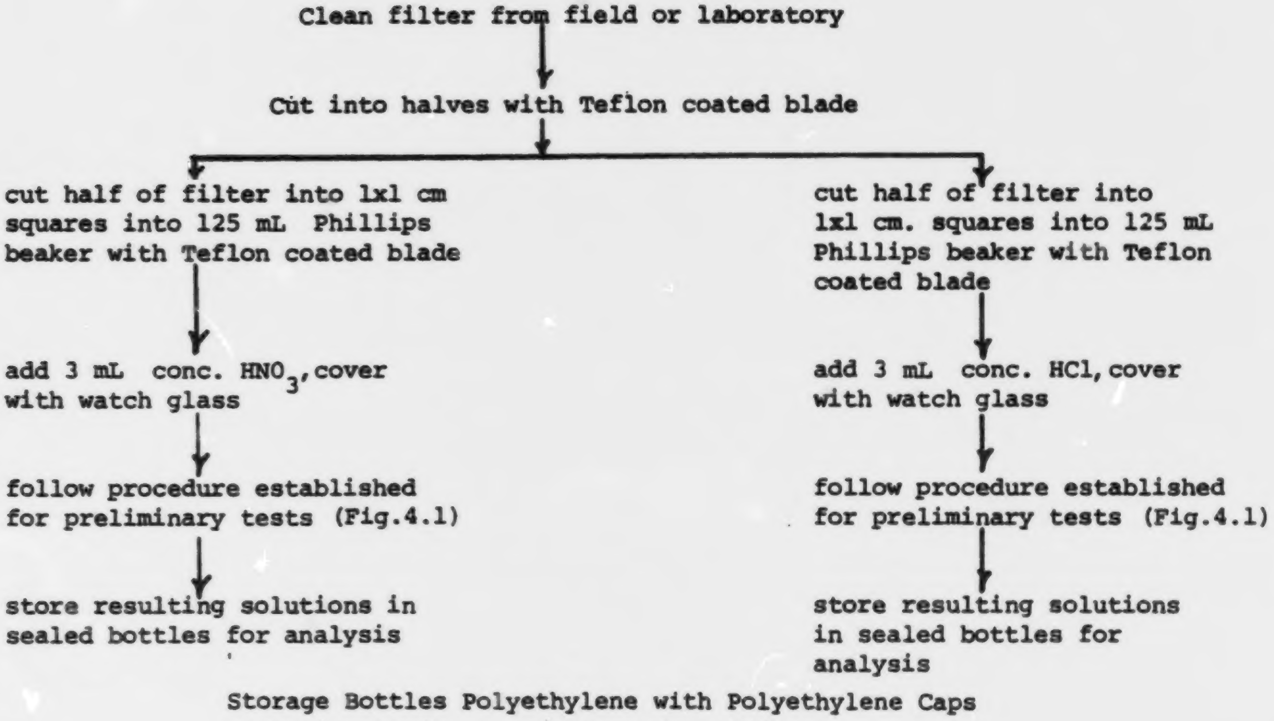
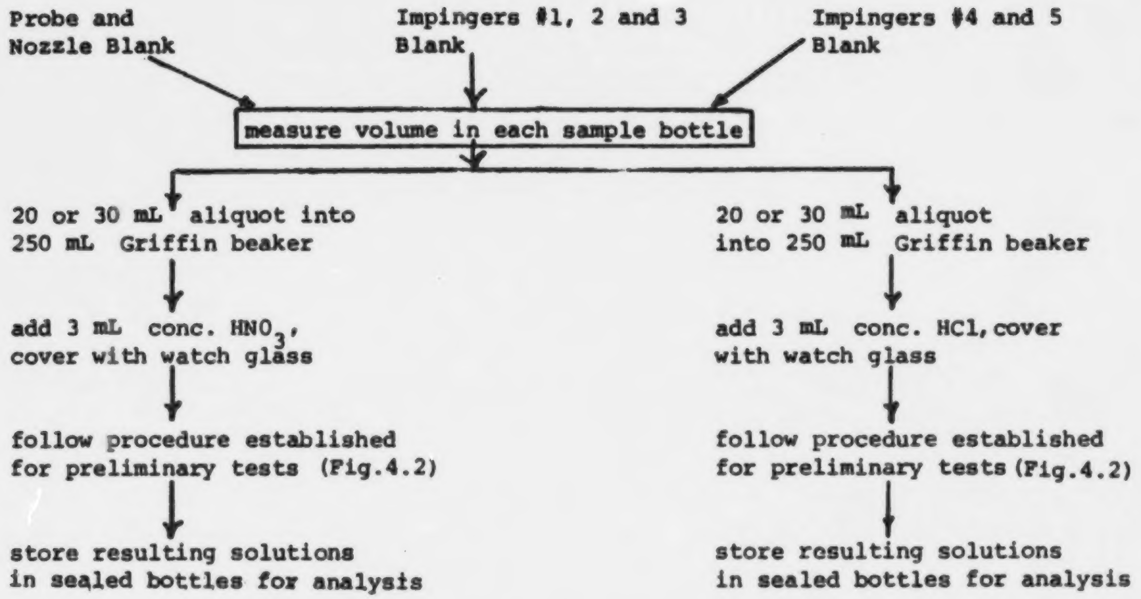
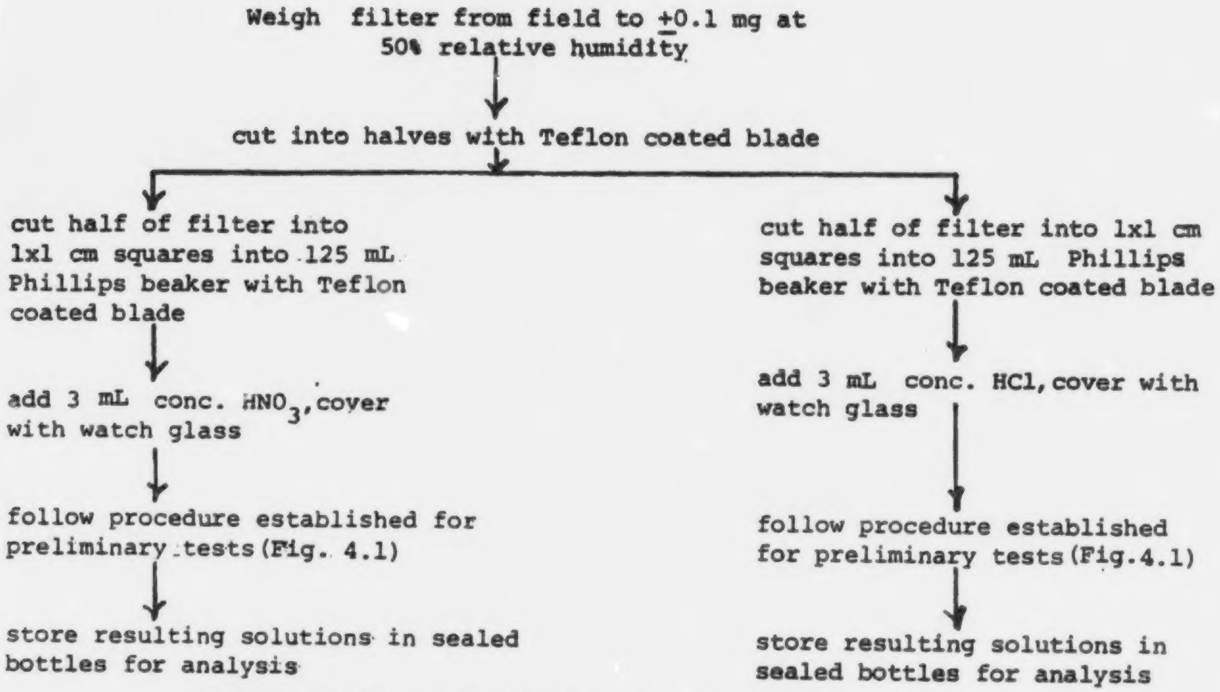

Clean filter from field or laboratory
Cut into halves with Teflon coated blade
cut half of filter into 1x1 cm squares into 125 mL Phillips beaker with Teflon coated blade
cut half of filter into 1x1 cm. squares into 125 mL Phillips beaker with Teflon coated blade
add 3 mL conc. HNO_3, cover with watch glass
add 3 mL conc. HCl, cover with watch glass
follow procedure established for preliminary tests (Fig.4.1)
follow procedure established for preliminary tests (Fig.4.1)
store resulting solutions in sealed bottles for analysis
store resulting solutions in sealed bottles for analysis
Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.3 Steps Involved in the Preparation of Field and Laboratory Filter Blanks for Preliminary Tests.


Probe and Nozzle Blank
Impingers #1, 2 and 3 Blank
Impingers #4 and 5 Blank
measure volume in each sample bottle
20 or 30 mL aliquot into 250 mL Griffin beaker
add 3 mL conc. HNO_3, cover with watch glass
follow procedure established for preliminary tests (Fig.4.2)
store resulting solutions in sealed bottles for analysis
20 or 30 mL aliquot into 250 mL Griffin beaker
add 3 mL conc. HCl, cover with watch glass
follow procedure established for preliminary tests (Fig.4.2)
store resulting solutions in sealed bottles for analysis

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.4 Steps Involved in the Preparation of Solution Blanks. (Preliminary Digestion Procedure)



Weigh filter from field to $\pm$0.1 mg at 50% relative humidity

cut into halves with Teflon coated blade

cut half of filter into 1x1 cm squares into 125 mL Phillips beaker with Teflon coated blade

add 3 mL conc. HNO_3, cover with watch glass

follow procedure established for preliminary tests (Fig. 4.1)

store resulting solutions in sealed bottles for analysis

cut half of filter into 1x1 cm squares into 125 mL Phillips beaker with Teflon coated blade

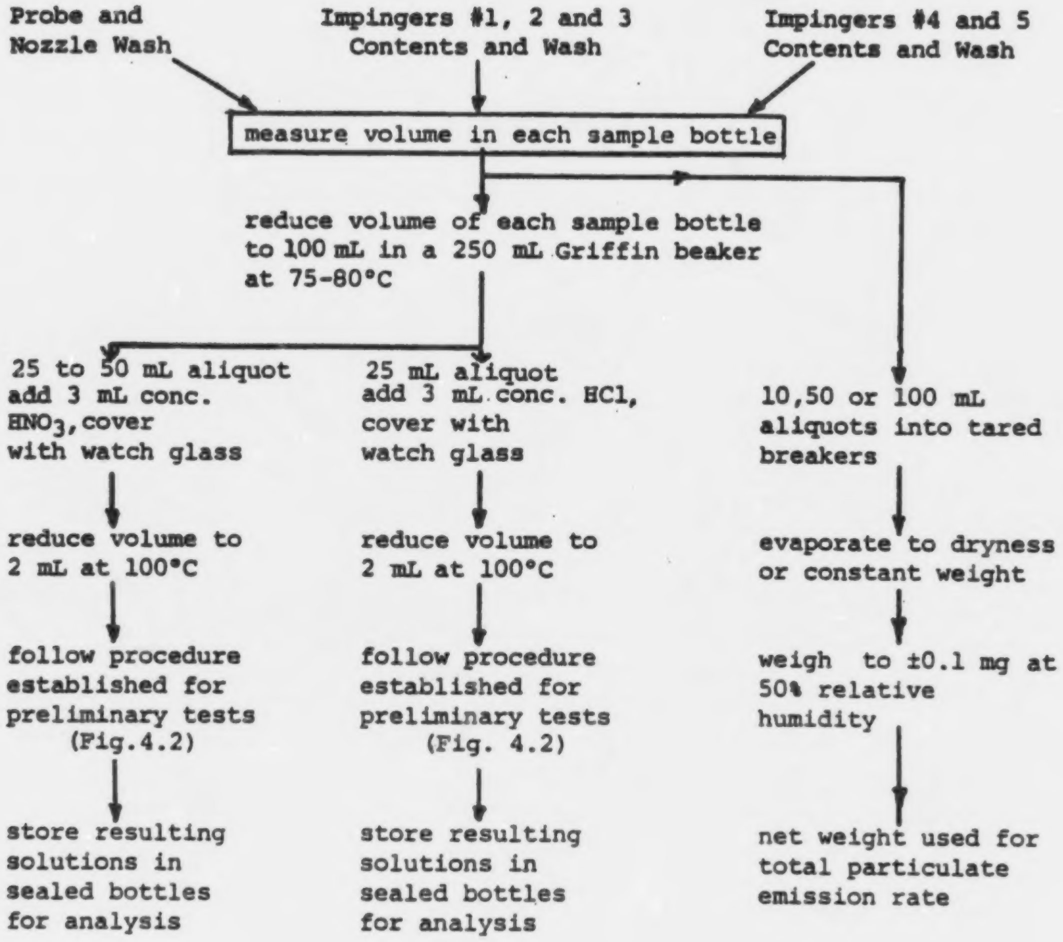
add 3 mL conc. HCl, cover with watch glass

follow procedure established for preliminary tests (Fig. 4.1)

store resulting solutions in sealed bottles for analysis

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.5: Treatment of Filters From Final Tests.


Probe and Nozzle Wash
Impingers #1, 2 and 3 Contents and Wash
Impingers #4 and 5 Contents and Wash
measure volume in each sample bottle
reduce volume of each sample bottle to 100 mL in a 250 mL Griffin beaker at 75-80°C
25 to 50 mL aliquot add 3 mL conc. HNO_3, cover with watch glass
reduce volume to 2 mL at 100°C
follow procedure established for preliminary tests (Fig.4.2)
store resulting solutions in sealed bottles for analysis
25 mL aliquot add 3 mL conc. HCl, cover with watch glass
reduce volume to 2 mL at 100°C
follow procedure established for preliminary tests (Fig. 4.2)
store resulting solutions in sealed bottles for analysis
10,50 or 100 mL aliquots into tared breakers
evaporate to dryness or constant weight
weigh to ±0.1 mg at 50% relative humidity
net weight used for total particulate emission rate

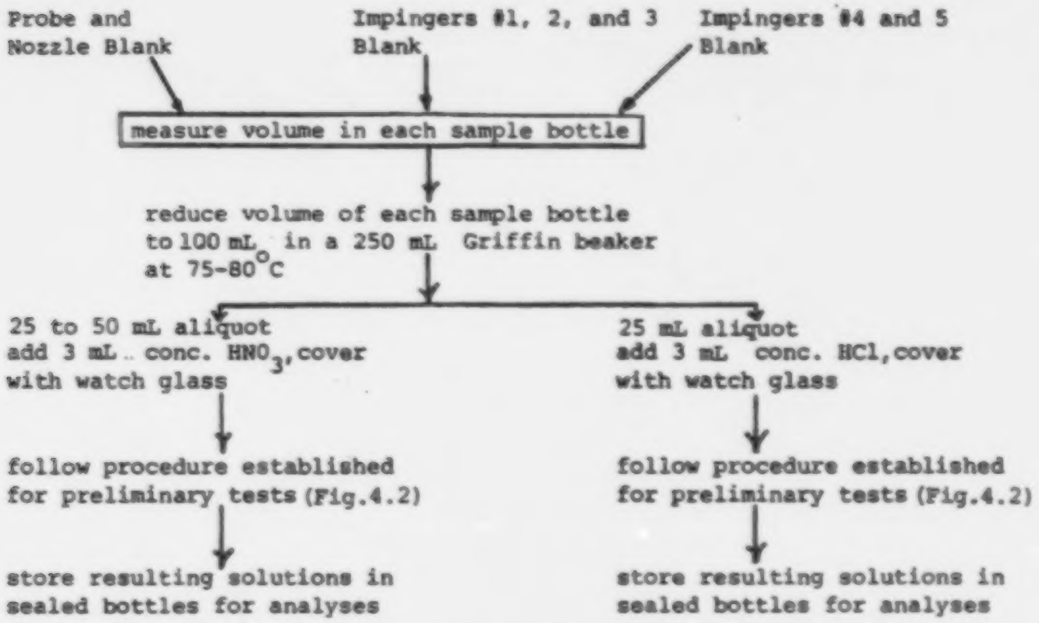
Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.6: Treatment of Solutions From Final Tests

Filter Analysis

Follow procedures established for field and laboratory blanks on filters used for preliminary survey

Solution Analyses



Probe and Nozzle Blank

Impingers #1, 2, and 3 Blank

Impingers #4 and 5 Blank

measure volume in each sample bottle

reduce volume of each sample bottle to 100 mL in a 250 mL Griffin beaker at 75-80°C

25 to 50 mL aliquot add 3 mL conc. HNO_3, cover with watch glass

follow procedure established for preliminary tests (Fig.4.2)

store resulting solutions in sealed bottles for analyses

25 mL aliquot add 3 mL conc. HCl, cover with watch glass

follow procedure established for preliminary tests (Fig.4.2)

store resulting solutions in sealed bottles for analyses

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.7: Preparation of Blanks for Filter and Solution Analyses

HNO_3 TREATMENT

Element	Amount Added uL
Mn	25
Ni	100
Cu	100
Ga	1000
Ge	1000
Mo	200
Pb	100
Sr	50
B	3000
Ag	25
Tl	200
In	1000
Te	500
Fe	100
As	1
Se	1
V	10
Hg	50
Cd	25
Cr	100

HCl TREATMENT

Element	Amount Added uL
Ti	2000
Co	100
Zn	25
Sb	200
Be	25
Al	1000
Sn	1000
Li	25
Sc	200

Table 4.2: Amounts of Standards Added to Filters for Recoveries Using 1000 ppm Standards

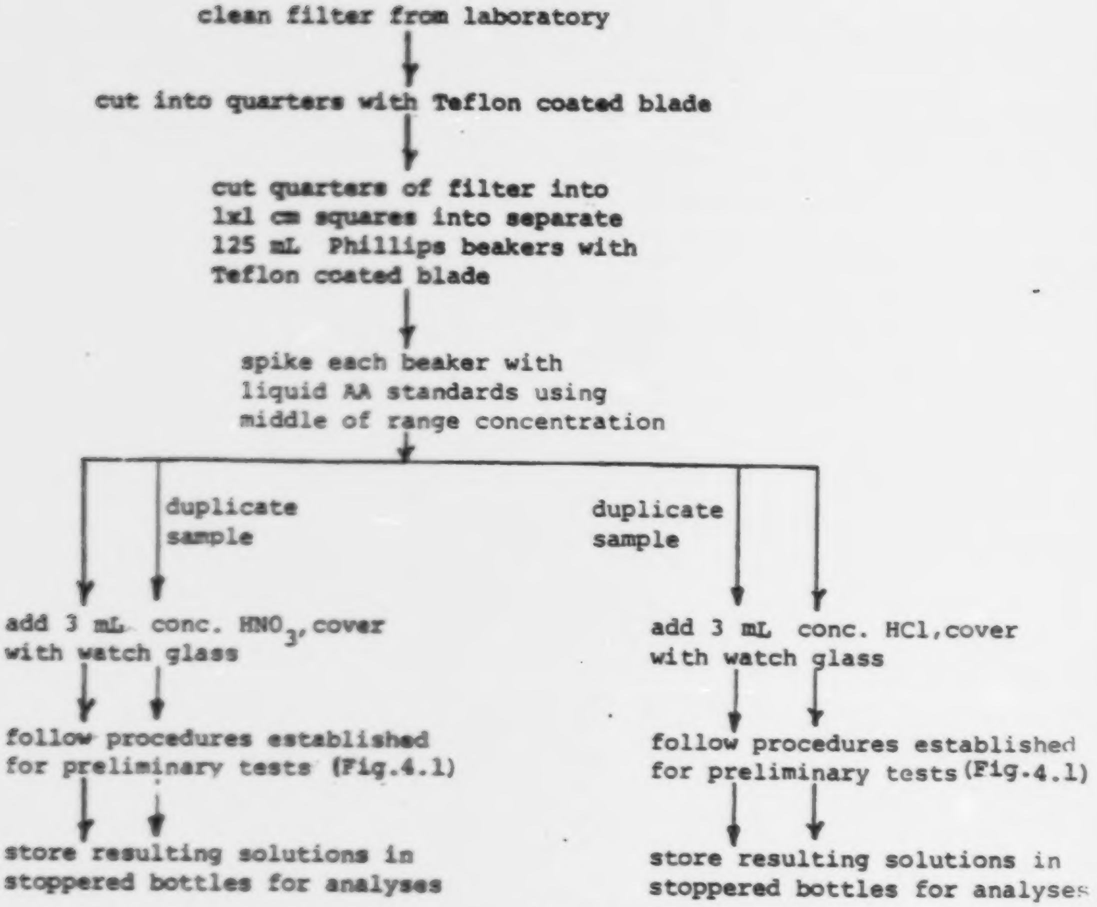
HNO_3 TREATMENT

Element	Amount Added uL
Mn	25
Ni	250
Cu	250
Ga	1000
Ge	1000
Mo	100
Cd	25
Pb	250
Sr	50
B	6000
Ag	25
Tl	500
In	3000
Te	500
Fe	250
As	5
Se	5
V	10
Hg	10
Cr	100

HCl TREATMENT

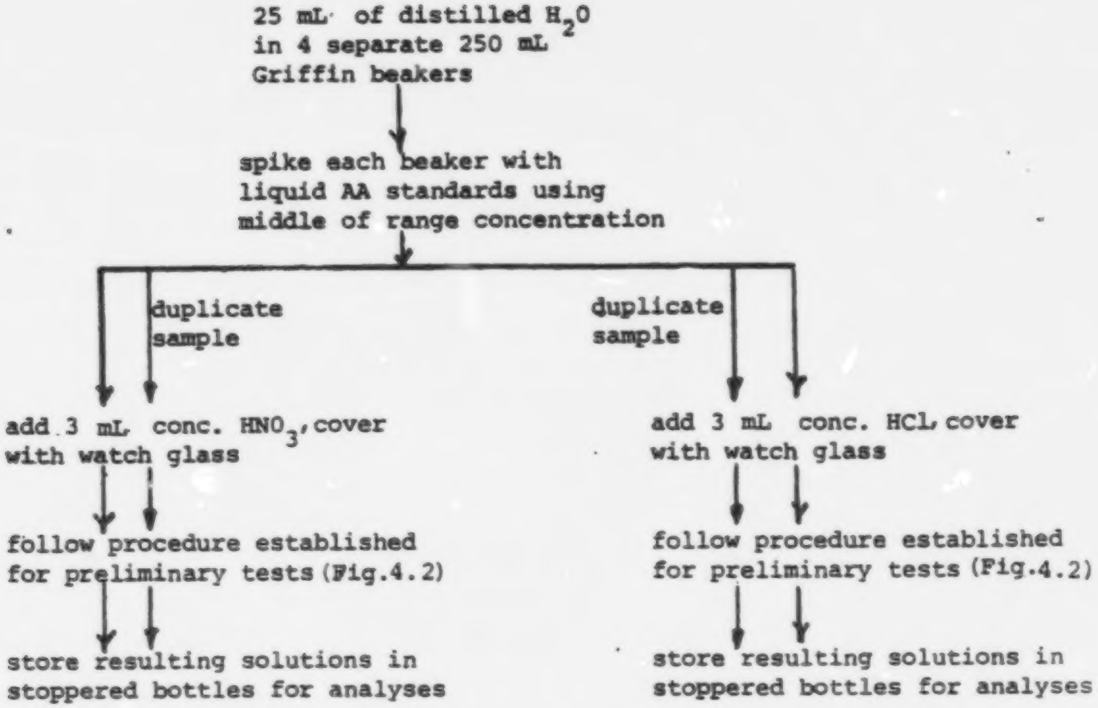
Element	Amount Added uL
Ti	1000
Co	100
Zn	25
Sb	200
Be	25
Al	1000
Sn	500
Li	25
Sc	200

Table 4.3 Amounts of Standards Added to Solutions for Recoveries Using 1000 ppm Standards


clean filter from laboratory
cut into quarters with Teflon coated blade
cut quarters of filter into 1x1 cm squares into separate 125 mL Phillips beakers with Teflon coated blade
spike each beaker with liquid AA standards using middle of range concentration
duplicate sample
duplicate sample
add 3 mL conc. HNO$_3$, cover with watch glass
add 3 mL conc. HCl, cover with watch glass
follow procedures established for preliminary tests (Fig.4.1)
follow procedures established for preliminary tests (Fig.4.1)
store resulting solutions in stoppered bottles for analyses
store resulting solutions in stoppered bottles for analyses

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.8: Preparation of Solutions for Component Recoveries From Filters


25 mL of distilled H_2O in 4 separate 250 mL Griffin beakers
spike each beaker with liquid AA standards using middle of range concentration
duplicate sample
duplicate sample
add 3 mL conc. HNO_3, cover with watch glass
add 3 mL conc. HCl cover with watch glass
follow procedure established for preliminary tests (Fig.4.2)
follow procedure established for preliminary tests (Fig.4.2)
store resulting solutions in stoppered bottles for analyses
store resulting solutions in stoppered bottles for analyses

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.9: Preparation of Solutions for Component Recoveries From Solutions

Limits of detection of each metal in mg/L were established by analyzing the lowest standard 10 times in order to determine the mean value of the absorbance and the standard deviation in terms of absorbance. Each detection limit shown in Table 4.1 was evaluated according to the expression:

$$\boxed{\text{Detection Limit (mg/L)} = 2 \times \frac{\text{standard deviation (absorbance units)}}{\text{mean of 10 runs (absorbance units)}} \times \text{standard concentration (mg/L)}}$$

Calibration curves were prepared by running all standards except the lowest ones twice each. Analyses of samples, blanks and recoveries were followed by running of the standards twice if less than 10 samples were being handled. Standards were checked every 10 samples when large numbers of samples were being processed.

Figure 4.10 illustrates the procedures adopted for atomic absorption spectrometric determination of the trace metals under consideration.

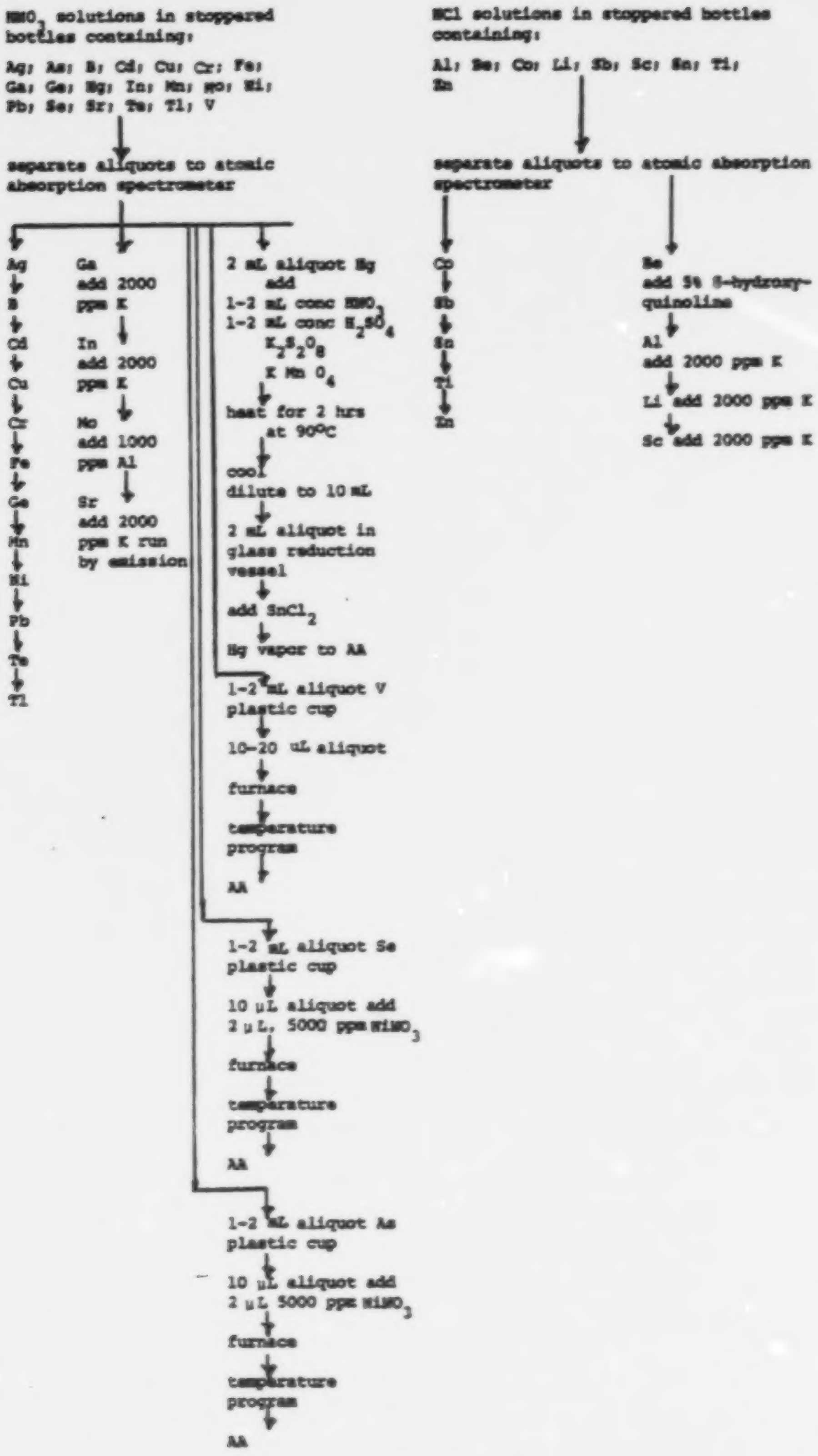

HNO3 solutions in stoppered bottles containing:
Ag; As; B; Cd; Cu; Cr; Fe; Ga; Ge; Hg; In; Mn; Mo; Ni; Pb; Se; Sr; Te; Tl; V
separate aliquots to atomic absorption spectrometer
Ag
B
Cd
Cu
Cr
Fe
Ge
Mn
Ni
Pb
Te
Tl
Ga add 2000 ppm K
In add 2000 ppm K
Mo add 1000 ppm Al
Sr add 2000 ppm K run by emission
2 mL aliquot Hg add
1-2 mL conc HNO3
1-2 mL conc H2SO4
K2S2O8
K Mn O4
heat for 2 hrs at 90°C
cool
dilute to 10 mL
2 mL aliquot in glass reduction vessel
add SnCl2
Hg vapor to AA
1-2 mL aliquot V plastic cup
10-20 uL aliquot
furnace
temperature program
AA
1-2 mL aliquot Se plastic cup
10 μL aliquot add 2 μL, 5000 ppm NiNO3
furnace
temperature program
AA
1-2 mL aliquot As plastic cup
10 μL aliquot add 2 μL 5000 ppm NiNO3
furnace
temperature program
AA
HCl solutions in stoppered bottles containing:
Al; Be; Co; Li; Sb; Sc; Sn; Ti; Zn
separate aliquots to atomic absorption spectrometer
Co
Sb
Sn
Ti
Zn
Be add 5% 8-hydroxy-quinoline
Al add 2000 ppm K
Li add 2000 ppm K
Sc add 2000 ppm K

Figure 4.10 Treatment of HNO_3 and HCl Solutions for Atomic Absorption Spectrometry

V. RESULTS

Comprehensive pre-sampling investigations indicated that meaningful results could only be obtained with pre-concentration of field blanks and liquids recovered from impingers and cold traps.

A. DEVELOPMENT

1. Pre-Test Program

Inductively Coupled Argon Plasma analysis of the distilled water samples showed no significant differences in quality with respect to metal content. No element exceeded the instrumental detection limits with the exception of silver (Ag) which was detected in the ERCB demineralized and University of Calgary normally distilled waters. The demineralized water from the ERCB laboratory in Edmonton, Alberta was selected because quality control could be more readily maintained throughout this study. The preparation of the demineralized water is described in Appendix II.

Analysis of two blank samples of the Baker Instra-Analyzed nitric acid that was to be used during this investigation identified the presence of arsenic (As), boron (B), beryllium (Be), cadmium (Cd), copper (Cu) molybdenum (Mo), nickel (Ni), antimony (Sb), selenium (Se), and tin (Sn). Table 5.1 shows that most of these metals were measured at levels of 1 to 2 times their detection limits. The manufacturer's lot analysis of the nitric acid is provided in Appendix II.

Table 5.2 summarizes the results of the ICAP analyses of nitric and hydrochloric acid solutions derived from the leaching of filter materials. On the basis of these data, the quartz micro fibre medium was selected for test purposes after Mr. Larry West(30) volunteered to provide 100 circles cut to 125 mm diameter requirements. Normally quartz microfibre filters are available in 8 x 10 inch sheets and circles of 55 mm diameter.

Table 5.3 provides a summary of the ICAP analysis of the 6M HNO_3 solutions used to wash the nozzle and probe liner, the three ice-bath impingers, the two cold trap impingers and connecting glassware.

2. Preliminary Field Testing at Canterra-Ram River Plant

The analytical procedures were finalized following field experiences with standard borosilicate glass fibre filters and solutions from the preliminary test at the Ram River Gas Plant.

a. Examination of Filter

The standard borosilicate glass fibre filter from the preliminary test at the Canterra-Ram River Gas Plant was unlike any other during this testing program.

Element

Blank Sample	As	B	Be	Cd	Cu
	Concentration in ppm				
1	< 0.125	0.015	0.002	< 0.010	< 0.010
2	0.204	< 0.013	< 0.001	0.013	0.015
Detection Limit	0.125	0.013	0.001	0.010	0.010
	Mo	Ni	Sb	Se	Sn
1	0.030	< 0.020	0.112*	< 0.300	< 0.150
2	0.047	0.056	1.864*	0.411	0.318
Detection Limit	0.025	0.020	*.***	0.300	0.150

* ICAP Interferences

Table 5.1: Summary of ICAP Analyses of Baker Instra-Analyzed Nitric Acid Blanks

	Filter					
	125 mm Borosilicate		125 mm micro-quartz		8 x 10 inch micro-quartz	
Element	HNO_3	HCl	HNO_3	HCl	HNO_3	HCl
Ag Silver	VL VL	- -	L L	VL VL	VL	-
Al Aluminum	H H	VH VH	VL VL	L L	H	VH
As Arsenic	L L	- -	- L	VL -	-	L
B Boron	H L	VH VH	L L	L VL	L	H
Be Beryllium	- -	- -	- -	- -	-	-
Cd Cadmium	- -	- -	VL -	- -	-	-
Co Cobalt	- -	- -	- -	- -	-	-
Cu Copper	VL VL	VL VL	VL -	VL VL	VL	VL
Fe Iron	L L	H H	VL VL	L L	L	L
Ga Gallium	- -	- -	- -	- -	-	-
Ge Germanium	- -	- -	- -	- -	-	-
Hg Mercury	L -	- L	- -	- -	-	-
In Indium	- -	- -	- -	- -	-	-
Li Lithium	- -	VL VL	- -	- -	-	-
Mn Manganese	VL -	VL VL	- -	- -	VL	VL
Mo Molybdenum	VL -	- -	- -	- -	-	-
Ni Nickel	VL VL	VL VL	VL VL	- VL	-	-
Pb Lead	- -	- -	- -	- -	-	-
Sb Antimony	- -	H H	- L	- -	-	L
Sc Scandium	- -	VL VL	- -	- -	-	-
Se Selenium	- -	VL -	- -	- -	-	-
Sn Tin	- -	VL VL	- -	- -	-	-
Sr Strontium	- -	VL VL	- -	- -	-	-
Te Tellurium	- -	VL -	- -	- -	-	-
Ti Titanium	L L	L H	- -	- -	VL	VL
Tl Thallium	- -	L -	- -	- -	-	-
V Vanadium	- -	VL VL	- -	- -	-	-
Zn Zinc	VL -	VL VL	VL VL	VL VL	VL	L

VL < 0.05 ppm L = 0.05 - 1 ppm

H = 1 - 10 ppm VH > 10 ppm

- = not detected

Table 5.2 Comparison of Filter Qualities on the Basis of Inductively Coupled Argon Plasma Spectrometry

Element	Sampling Train Component						
	Probe and Nozzle (Washes)	Filter (Leaching)	Impingers (Washes)			Glass Connectors (Washes)	
			1	2 & 3	4 & 5	1	2
Ag Silver	-	-	-	-	-	-	-
Al Aluminum	-	-	-	-	-	-	-
As Arsenic	L	-	L	L	-	L	L
B Boron	VL	-	-	-	-	-	-
Be Beryllium	-	VL	-	-	-	-	-
Cd Cadmium	-	-	-	-	-	-	-
Co Cobalt	-	-	L	-	-	-	L
Cu Copper	L	VL	VL	-	-	L	-
Fe Iron	L	VL	VL	VL	VL	L	-
Ga Gallium	-	-	-	-	-	-	-
Ge Germanium	-	-	-	-	-	-	-
Hg Mercury	L	-	L	-	VL	-	-
In Indium	-	-	-	-	-	-	-
Li Lithium	-	-	-	-	-	-	-
Mn Manganese	-	-	-	-	-	-	-
Mo Molybdenum	VL	VL	VL	VL	-	-	VL
Ni Nickel	L	L	L	L	-	L	L
Pb Lead	-	-	-	-	-	L	-
Sb Antimony	H*	H*	H*	H*	H*	H*	H*
Sc Scandium	-	-	-	-	-	-	-
Se Selenium	L	L	L	-	L	-	L
Sn Tin	L	L	L	L	L	L	L
Sr Strontium	-	-	-	-	-	-	-
Te Tellurium	-	-	-	L	-	-	-
Ti Titanium	-	-	-	VL	-	-	-
Tl Thallium	L	L	L	L	-	L	L
V Vanadium	-	-	-	-	-	-	-
Zn Zinc	VL	-	-	-	-	-	-

VL < 0.05 ppm

L = 0.05 - 1 ppm

H = 1 - 10 ppm

VH > 10 ppm

- = not detected

* see Table 5.1

Table 5.3 Summary of Metal Levels in Probe, Filter and Impinger Washes as Determined by Inductively Coupled Argon Plasma Analyses

High performance liquid chromatographic (HPLC) analysis of the methylene chloride used to extract one quarter of the filter showed no evidence of any single ring or polycyclic aromatic compounds. Table 5.4 provides the results of the subsequent SEM/EDS analysis of the residue left on the filter section after the methylene chloride extraction.

Element	Average Weight %	Average Blank Weight %	Particle Weight %
Al	3.1	2.2	1.2
Ca	17.9	15.9	7.7
Cu	0.2	0.3	0.0
Cr	0.0	0.1	0.2
Fe	0.5	0.4	0.4
Mg	1.1	0.6	5.7
Ti	0.4	0.4	0.1
Si	15.8	12.9	5.2
S	2.0	0.3	16.2

Table 5.4 Results of SEM/EDS Analysis of Residue on Filter From Preliminary Ram River Gas Plant Test.

Significant differences between the edge (blank) and centre of the filter were found for calcium (Ca), magnesium (Mg), silicon (Si), and sulfur (S).

The filter section sent to the University of Toronto, for neutron activation analysis (NAA) as well as identification of any radioactive components that might have been collected, did not show any evidence of natural radioactivity(31).

Table 5.5 provides a comparison of the results of neutron activation analysis (NAA) of the Ram River Gas Plant preliminary test filter quarter, and a blank from the same lot(31).

The results of atomic absorption (AA) analysis of solutions prepared from the preliminary test filter, according to the procedures outlined in Figure 4.1 are provided in Table 5.6. Only zinc (Zn) was detected on the 2 filter quarters reserved for atomic absorption (AA) analysis. Similar treatment of a blank filter showed contamination by aluminum (Al), chromium (Cr), and Zinc (Zn).

It must be emphasized that the neutron activation analysis (NAA) of Ram River Gas Plant preliminary test filter and field solution specimens was implemented only as a screening technique to establish the potential presence of the metals of interest. Although this procedure is often capable of detecting some metals at levels below those attainable with atomic absorption (AA) analysis (lower LOD values with [NAA]) it was not applicable to the entire range of elements pertiment to this investigation.

	Filter	
	Blank	Ram River Test
Element	(micrograms)	
Ag	< 140	< 140
Al	$(10 \pm 1) \times 10^3$	8.6×10^3
Ba	110 ± 5	120
Ca	$(20 \pm 1) \times 10^3$	19×10^3
Co	$< 410 \times 10^{-3}$	$< 410 \times 10^{-3}$
Cu	< 32	< 32
Mn	2.6 ± 0.1	3.0 ± 0.1
Na	400 ± 10	390
Sn	< 37	< 37
Sr	$< 230 \times 10^{-3}$	$< 200 \times 10^{-3}$
Ti	700 ± 30	750
U	$(570 \pm 30) \times 10^{-3}$	590×10^{-3}
V	9.0 ± 0.5	7.5
S	$< 33 \times 10^3$	$< 30 \times 10^3$

Table 5.5: Neutron Activation Analysis Results for Blank and Preliminary Ram River Test Filters (31)

Sample Analyses — Test No. Prelim — Date August 25, 1982 — Ram River

Sample From	P&N	IMP 1	IMP 2,3	IMP 4,5	Filter	Elemental Weight ug	Elemental Concentration ug/ref	Elemental Emission Rate gm/hr
Volume (ml)	490	470	475	190		$E_R = 3.2 \times 10^4$ kg/d (total)		
Total Particulate (mg)	25	-	4400	-	12	$E_R = 2.6 \times 10^2$ kg/d (front end)		
Ag Silver	29	28	29	11	10	110	1.7	32
Al Aluminum	490	470	480	190	1000	2600	42	780
As Arsenic	0.15	0.14	0.14	0.06	1.0	1.5	0.02	0.44
B Boron	3900	3800	3800	1500	800	14000	220	4100
Be Beryllium	15	19	19	7.6	3.0	63	1.0	19
Cd Cadmium	20	19	19	7.6	4	69	1.1	20
Co Cobalt	98	94	95	38	20	350	5.5	100
Cr Chromium	200	190	190	76	40	690	11	200
Cu Copper	98	94	95	38	20	350	5.5	100
Fe Iron	$\boxed{290}$	190	190	76	40	$\boxed{790}$	$\boxed{13}$	$\boxed{230}$
Ga Gallium	2000	1900	1900	760	400	6900	110	2000
Ge Germanium	2000	1900	1900	760	400	6900	110	2000
Hg Mercury	4.9	4.7	4.8	1.9	20	36	0.58	11
In Indium	2000	1900	1900	760	400	6900	110	2000
Li Lithium	9.8	9.4	9.5	3.8	2.0	35	0.55	10
Mn Manganese	49	47	48	19	10	170	28	51
Mo Molybdenum	490	470	480	190	100	1700	28	510
Ni Nickel	200	190	190	76	40	690	0.18	3.3
Pb Lead	200	190	190	76	40	690	11	200
Sb Antimony	200	190	190	76	40	690	11	200
Sc Scandium	150	140	140	57	30	520	8.3	150
Se Selenium	9.8	9.4	9.5	3.8	2.0	35	0.55	10
Sn Tin	980	940	950	380	100	3400	54	990
Sr Strontium	98	94	95	38	20	350	5.5	100
Te Tellurium	390	380	380	150	80	1400	22	410
Ti Titanium	980	940	950	380	200	3500	55	1000
Tl Thallium	290	280	290	110	60	1000	17	310
V Vanadium	29	28	29	11	4.0	100	1.6	30
Zn Zinc	$\boxed{250}$	$\boxed{38}$	$\boxed{48}$	$\boxed{25}$	$\boxed{880}$	$\boxed{1200}$	$\boxed{20}$	$\boxed{370}$

All elements except those in boxes ☐ are below the limit of detection

Table 5.6: Summary of Atomic Absorption Analysis of Preliminary Ram River Test Filter, Impinger Solutions and Probe and Nozzle Wash

b. Examination of Impinger Solutions

The impinger solutions from the preliminary test at the Ram River Gas Plant were distinctly different from those collected during subsequent tests and from those at other gas plants. Neutron activation analysis (NAA) of aliquots of the straw colored liquids yielded the results detailed in Table 5.7. Measurable amounts of aluminum (Al), calcium (Ca), manganese (Mn), sodium (Na), titanium (Ti), and sulfur (S) were detected in impingers #1, (#2 and #3) and (#4 and #5).

According to Table 5.6, atomic absorption (AA) analysis of the same impinger solutions, following the procedures illustrated in Figure 4.2, established the presence of zinc (Zn) only.

c. Examination of Probe and Nozzle Wash

Table 5.7 shows that neutron activation analysis (NAA) identified the presence of aluminum (Al), copper (Cu), manganese (Mn), sodium (Na) and titanium (Ti) in the liquid used to wash the probe and nozzle after the preliminary test at the Ram River Gas Plant. The data in Table 5.6 indicate that only iron (Fe) and zinc (Zn) were present in measurable quantities in the probe and nozzle wash.

B. PLANT TESTS

Four particulate matter sampling tests (1 preliminary and 3 official) were conducted at the following locations:

- o Gulf Oil Canada Limited-Strachan Gas Plant between 21-24 August, 1982
- o Canterra Energy Limited-Ram River Gas Plant between 25-28, August, 1982
- o Shell Canada Limited-Jumping Pound Gas Plant between 30 August - 2 September 1982.

All sample acquisition was carried out with borosilicate glass lined probes.

Appendix IV details the field data, isokineticity checks, individual metal concentrations and emission rates for the 8 tests for which sample integrity was maintained during shipment.

Appendix V provides the sour gas plant operating data collected during the actual testing periods by ERCB personnel.

Tables 5.8 to 5.13 summarize the laboratory recoveries of the 29 metals from spiked filter and liquid samples.

Element	Concentration (ppb)				Atomic Absorption Detection Limit (ppb)
	Probe & Nozzle	Impinger #1	Impingers #2 & #3	Impingers #4 & #5	
Ag	< 18	< 19	< 18	< 15	50
Al	250	190	130	210 ± 10	1000
Ba	< 380	< 380	< 380	< 380	--
Ca	< 2000	6500	< 2900	5800 ± 1200	--
Co	< 5.7	< 5.9	< 5.8	< 5.6	200
Cu	440 ± 30	< 100	< 100	< 78	100
Mn	23	4.1	4.4	12 ± 1	50
Na	890	540	890	1300 ± 140	--
Sn	< 2000	< 2000	< 2000	< 2000	1000
Sr	< 640	< 600	< 600	< 600	50
Ti	790	< 250	340	390 ± 80	1000
U	< 1.7	< 1.7	< 1.7	< 1.7	--
V	< 0.7	0.9	< 0.7	< 0.7	20
S (ppm)	< 100	8900	6400	2000 ± 140	--

Table 5.7: Results of Neutron Activation Analysis of Probe and Nozzle Wash and Impinger Liquids from Preliminary Ram River Test [31]

STRACHAN/filters

	Tests 2 & 3		Average
	%	%	%
Ag Silver	100	95	98±4
Al Aluminum	150	230	190±57
As Arsenic	200	200	200±0
B Boron	226	252	239±18
Be Beryllium	96	88	92±6
Cd Cadmium	92	100	96±6
Co Cobalt	78	85	82±5
Cr Chromium	115	105	110±7
Cu Copper	95	100	98±4
Fe Iron	105	109	107±3
Ga Gallium	90	95	93±4
Ge Germanium	36	48	42±8
Hg Mercury	80	80	80±0
In Indium	90	95	93±4
Li Lithium	84	104	94±14
Mn Manganese	116	124	120±6
Mo Molybdenum	73	75	74±1
Ni Nickel	100	100	100±0
Pb Lead	105	100	103±4
Sb Antimony	68	69	69±0
Sc Scandium	73	82	78±6
Se Selenium	95	70	83±18
Sn Tin	115	115	115±0
Sr Strontium	370	360	365±7
Te Tellurium	95	99	97±3
Ti Titanium	119	129	124±7
Tl Thallium	85	88	87±2
V Vanadium	260	260	260±0
Zn Zinc	100	112	106±8

Table 5.8 Laboratory Recoveries From Spiked Filters
(Strachan Plant Sample Analysis)

STRACHAN/liquids

	Tests 2 & 3		Average
Ag Silver	100	80	90±14
Al Aluminum	68	78	73±7
As Arsenic	220	220	220±0
B Boron	82	82	82±0
Be Beryllium	96	92	94±3
Cd Cadmium	104	104	104±0
Co Cobalt	90	90	90±0
Cr Chromium	125	115	120±7
Cu Copper	105	105	105±0
Fe Iron	105	95	100±7
Ga Gallium	95	95	95±0
Ge Germanium	100	105	103±4
Hg Mercury	85	85	85±0
In Indium	105	100	103±4
Li Lithium	92	92	92±0
Mn Manganese	110	102	106±6
Mo Molybdenum	88	88	88±0
Ni Nickel	110	105	108±4
Pb Lead	110	110	110±0
Sb Antimony	102	102	102±0
Sc Scandium	99	104	102±4
Se Selenium	80	70	75±7
Sn Tin	115	115	115±0
Sr Strontium	200	200	210±14
Te Tellurium	110	110	110±0
Ti Titanium	143	135	139±6
Tl Thallium	93	90	92±2
V Vanadium	220	240	230±14
Zn Zinc	112	120	116±6

Table 5.9 Laboratory Recoveries From Spiked Liquids (Strachan Plant Sample Analysis)

RAMRIVER/filters

	Tests Prelim		Average	Tests 1 & 3		Average
	%	%	%	%	%	%
Ag Silver	5	5	5±0	100	95	98±4
Al Aluminum	470	550	510±57	150	230	190±57
As Arsenic	filter contamination			200	200	200±0
B Boron	370	400	385±21	226	252	239±18
Be Beryllium	80	84	82±3	96	88	92±6
Cd Cadmium	92	92	92±0	92	100	96±6
Co Cobalt	88	85	87±2	78	85	82±5
Cu Copper	90	95	93±4	95	100	98±4
Cr Chromium	ns	ns	-	115	105	110±7
Fe Iron	155	165	160±7	105	109	107±3
Ga Gallium	90	90	90±0	90	95	93±4
Ge Germanium	70	60	65±7	36	48	42±8
Hg Mercury	100	150	125±35	80	80	80±0
In Indium	95	95	95±0	90	95	93±4
Li Lithium	100	88	94±8	84	104	94±14
Mn Manganese	104	100	102±3	116	124	120±6
Mo Molybdenum	110	125	118±11	73	75	74±1
Ni Nickel	90	90	90±0	100	100	100±0
Pb Lead	105	105	105±0	105	100	103±4
Sb Antimony	113	105	109±6	68	69	69±0
Sc Scandium	60	65	63±4	73	82	78±6
Se Selenium	25	25	25±0	95	70	83±18
Sn Tin	103	100	102±2	115	115	115±0
Sr Strontium	320	320	320±0	370	360	365±7
Te Tellurium	51	48	50±2	95	99	97±3
Ti Titanium	80	85	83±4	119	129	124±7
Tl Thallium	95	90	93±4	85	88	87±2
V Vanadium	ns	ns	-	260	260	260±0
Zn Zinc	72	76	74±3	100	112	106±8

Table 5.10 Laboratory Recoveries From Spiked Filters
(Ram River Plant Sample Analysis)

				RAMRIVER/liquids		
	Tests	Prelim	Average	Tests 1	and 3	Average
	%	%	%	%	%	%
Ag Silver	ns	ns	-	100	80	90±14
Al Aluminum	70	82	76±9	68	78	73±7
As Arsenic	132	156	144±17	220	220	220±0
B Boron	100	100	100±0	82	82	82±0
Be Beryllium	76	80	78±3	96	92	94±3
Cd Cadmium	100	96	98±3	104	104	104±0
Co Cobalt	120	96	108±17	90	90	90±0
Cr Chromium	ns	ns	-	125	115	120±7
Cu Copper	104	100	102±3	105	105	105±0
Fe Iron	104	112	108±6	105	95	100±7
Ga Gallium	110	100	103±4	95	95	95±0
Ge Germanium	102	114	108±8	100	105	103±4
Hg Mercury	116	116	116±0	85	85	85±0
In Indium	110	100	105±7	105	100	103±4
Li Lithium	48	60	54±8	92	92	92±0
Mn Manganese	112	116	114±3	110	102	106±6
Mo Molybdenum	120	132	126±8	88	88	88±0
Ni Nickel	100	100	100±0	110	105	108±4
Pb Lead	110	113	112±2	110	110	110±0
Sb Antimony	99	130	115±22	102	102	102±0
Sc Scandium	85	110	98±18	99	104	102±4
Se Selenium	ns	ns	-	80	70	75±7
Sn Tin	76	124	100±34	115	115	115±0
Sr Strontium	132	144	138±8	200	200	210±14
Te Tellurium	88	75	82±9	110	110	110±0
Ti Titanium	84	82	83±1	143	135	139±6
Tl Thallium	102	102	102±0	220	240	92±2
V Vanadium	144	102	123±30	220	240	230±14
Zn Zinc	88	112	100±17	112	120	116±6

Table 5.11 Laboratory Recoveries From Spiked Liquids
(Ram River Plant Sample Analysis)

ELEMENT	JUMPING POUND/filter Tests Prelim, 2,3		AVERAGE
	Recovery %		%
Ag Silver	105*	110*	108±4
Al Aluminum	83	85	84±1
As Arsenic	160	160	160±0
B Boron	97	90	94±5
Be Beryllium	100	100	100±0
Cd Cadmium	96	96	96±0
Co Cobalt	85	83	84±1
Cr Chromium	85	85	85±0
Cu Copper	100	100	100±0
Fe Iron	115	115	115±0
Ga Gallium	115	115	115±0
Ge Germanium	90	90	90±0
Hg Mercury	92	92	92±0
In Indium	97	105	101±6
Li Lithium	92	92	92±0
Mn Manganese	70	64	67±4
Mo Molybdenum	93	93	93±0
Ni Nickel	100	100	100±0
Pb Lead	100	100	100±0
Sb Antimony	87	92	90±4
Sc Scandium	80	80	80±0
Se Selenium	-	-	-
Sn Tin	90	85	88±4
Sr Strontium	110	110	110±4
Te Tellurium	88	90	89±1
Ti Titanium	83	81	82±1
Tl Thallium	110	110	110±0
V Vanadium	125	135	130±7
Zn Zinc	108	112	110±3

*new standard used

Table 5.12 Laboratory Recoveries From Spiked Filters
(Jumping Pound Plant Sample Analysis)

ELEMENT	JUMPING POUND/liquids Tests Prelim 2,3 Recovery %		AVERAGE %
Ag Silver	105*	110*	108±4
Al Aluminum	88	93	91±4
As Arsenic	160	160	160±0
B Boron	97	90	97±5
Be Beryllium	120	120	120±0
Cd Cadmium	96	96	96±0
Co Cobalt	100	100	100±0
Cr Chromium	85	85	85±0
Cu Copper	100	100	100±0
Fe Iron	115	115	115±0
Ga Gallium	115	115	115±0
Ge Germanium	90	90	90±0
Hg Mercury	92	92	92±0
In Indium	97	105	101±6
Li Lithium	120	120	120±0
Mn Manganese	70	64	67±4
Mo Molybdenum	93	93	93±0
Ni Nickel	100	100	100±0
Pb Lead	100	100	100±0
Sb Antimony	110	99	105±8
Sc Scandium	95	95	95±0
Se Selenium	-	-	-
Sn Tin	110	110	110±0
Sr Strontium	110	110	110±0
Te Tellurium	88	90	89±1
Ti Titanium	120	120	120±0
Tl Thallium	110	110	110±0
V Vanadium	125	135	130±7
Zn Zinc	130	130	130±0

*new standard used

Table 5.13 Laboratory Recoveries From Spiked Liquids (Jumping Pound Plant Sample Analysis)

The trace element emission rates of metals whose presence was "detected", are summarized in Figures 5.1, 5.2, and 5.3. These values were determined employing the measured elemental concentrations and values corresponding to the limits of detection (LOD) for the four samples recovered from the sampling train for each test. Consequently, the mean emission rates corresponding to the full circles represent maximum possible values. The upper and lower bounds indicate the range of emission rates for each plant tested. Open circles indicate the average of the maximum emission rates which correspond to the use of LOD values only.

Discussions following the 66th Canadian Chemical Conference(32) and peer reviews(33-36) indicated the necessity for carefully defining criteria used to "establish" the presence of any metal in the incinerator stack gases at significant levels because of the sporadic appearances and low concentrations associated with the elements.

A metal is reported as being present in significant amounts if the element was "detected"

i) in more than one-half of the tests or

ii) at a concentration 3 times the limit of detection (LOD).

Table 5.14 summarizes the plant emission rates using these criteria.

Appendix VI details the maximum possible incinerator stack emission rates that could exist without detection of any metallic species employing the sample recovery and analytical procedures developed for this investigation. The effects of preconcentration, total gas sample volume collected and instrumental limits of detection on the maximum possible rates are discussed in detail.

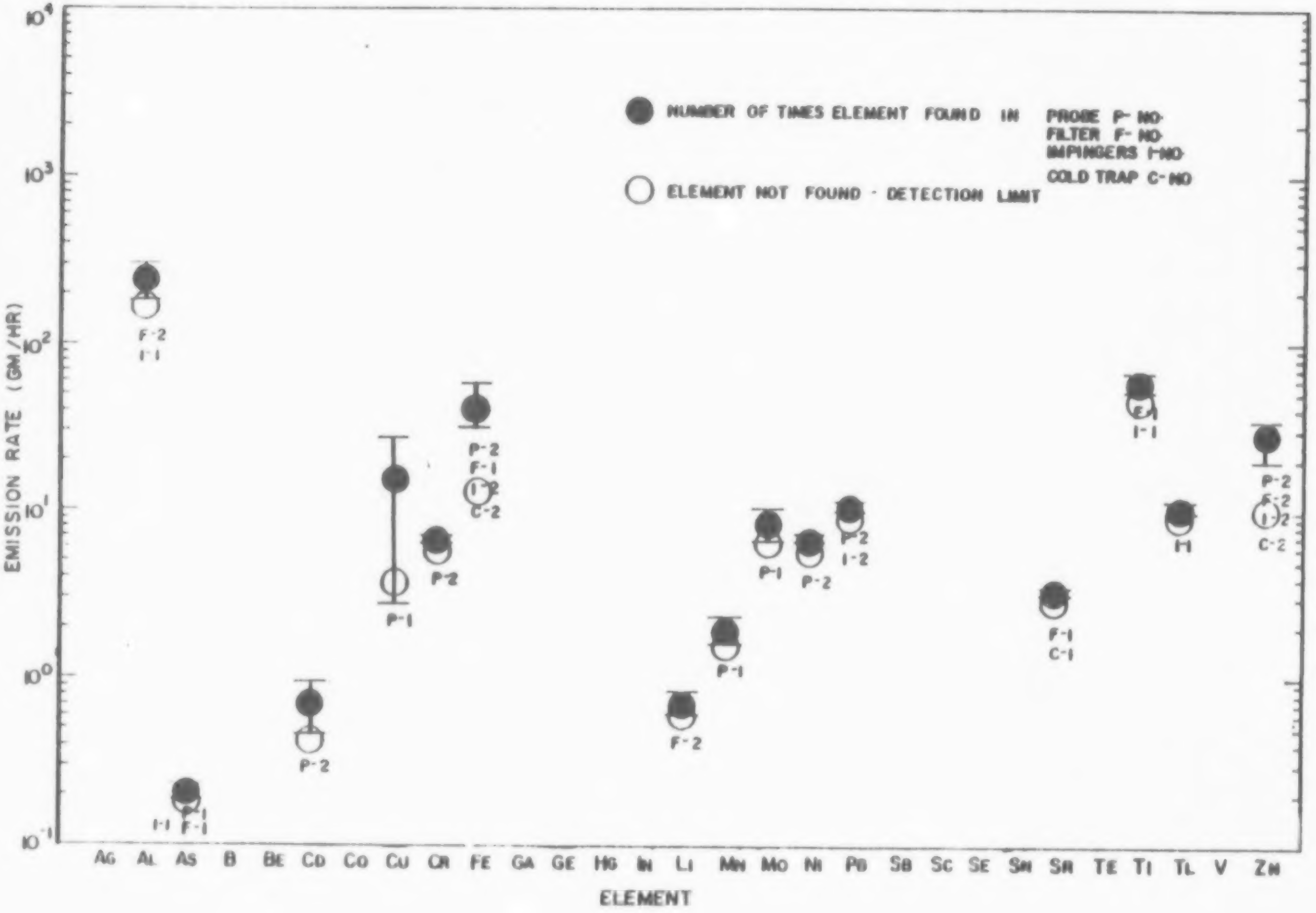


Figure 5.1: Maximum Emission Rates of Metals Whose Presence was "Detected" in Gulf-Strachan Incinerator Stack Gases Using a Borosilicate Glass Liner

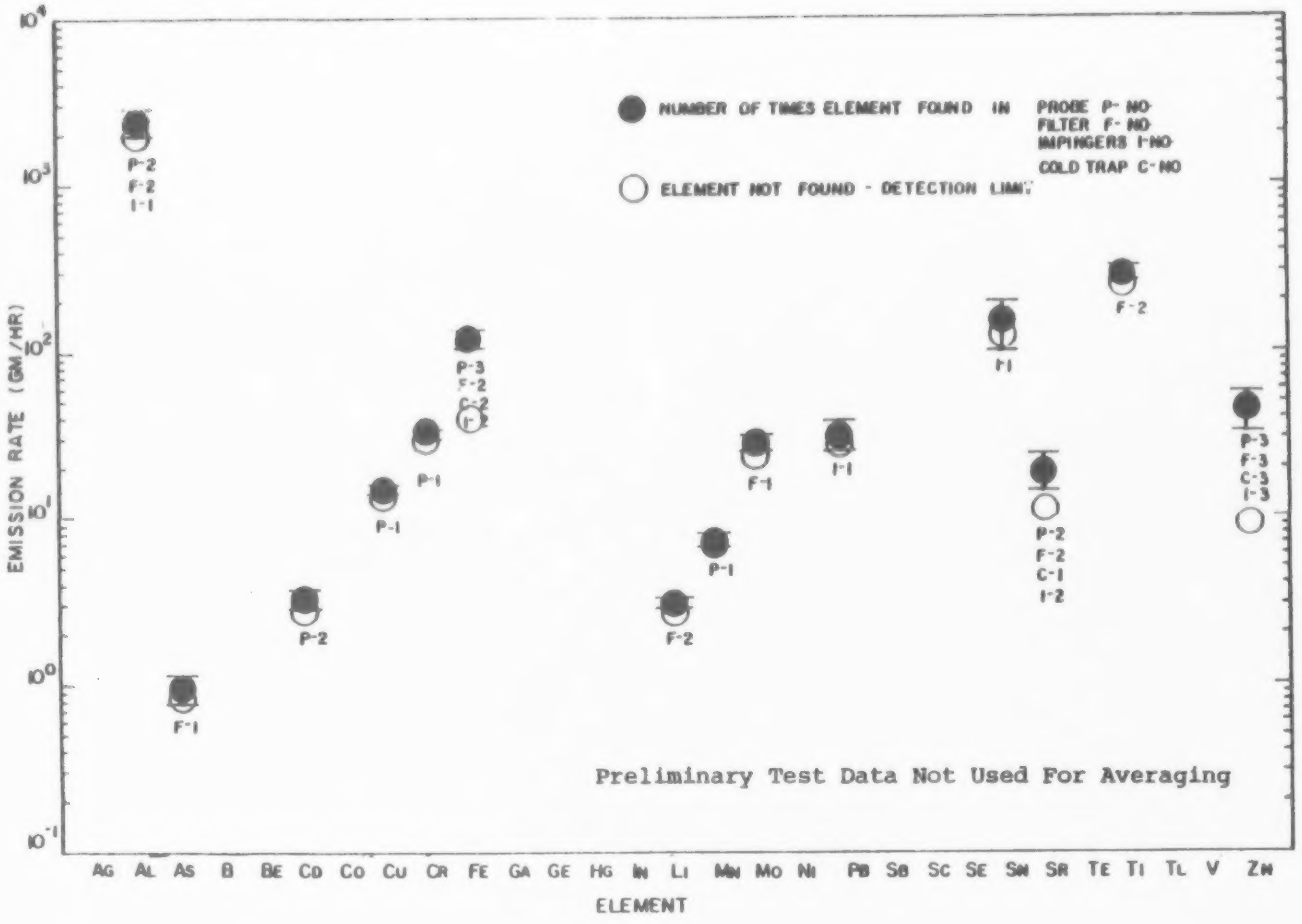


Figure 5.2: Maximum Emission Rates of Metals Whose Presence was "Detected" in Canterra-Ram River Incinerator Stack Gases using a Borosilicate Glass Liner

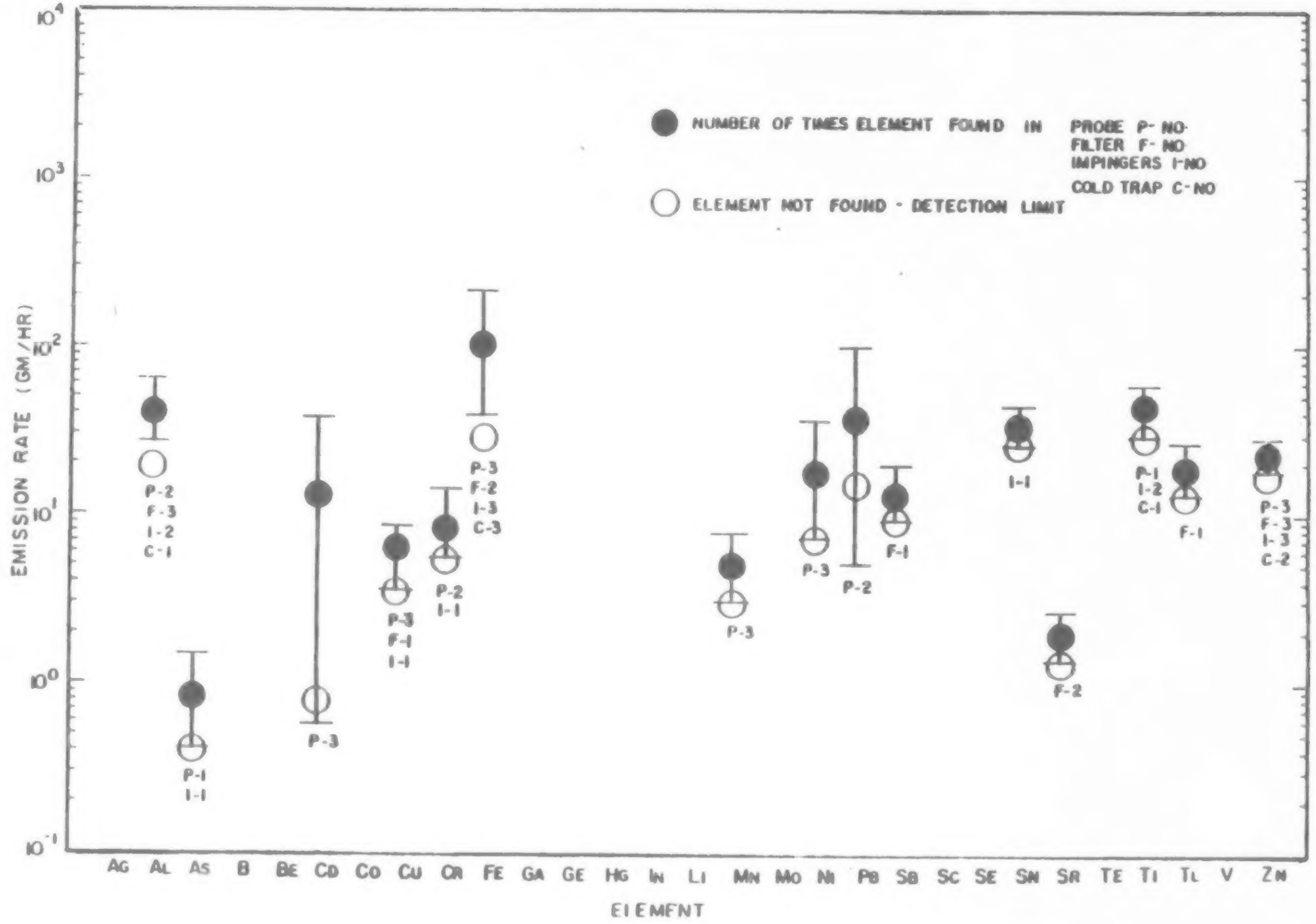


Figure 5.3: Maximum Emission Rates of Metals Whose Presence was "Detected" in Shell-Jumping Pound Incinerator Stack Gases Using a Borosilicate Glass Liner

Plant Test	Date d/m/y	Liner	Plant Production $10^6 m^3/d$	Average Stack Temperature T_s (°F)	Average Moisture by Condensation B_{wo}	Average Stack Velocity V_s ft/s	Average Volumetric Flowrate Q_s acfm	Average SO_2 Concentration % by Volume	Metal Species Emission Rate g/h													Emission Rate	
									Al	As	Cd	Cr	Cu	Fe	Li	Mo	Ni	Pb	Sr	Ti	Zn	Front End 10^3 kg/d	Total 10^6 kg/d
Gulf Strachan #2	23/8/82	G	3.70	940	0.107	19.5	230,000	0.31	380	0.2	0.9	6.7	2.6	49	0.8	–	6.7	10	–	65	17	0.5	*3.1
#3	24/8/82	G	2.32	940	0.165	19.6	230,000	0.30	160	0.2	0.5	6.5	–	28	0.6	–	6.5	9.0	–	52	21	1.1	*5.9
Canterra Ram River *Preliminary	25/8/82	G	5.98	1079	0.247	54.6	1,000,000	0.22	*	–	*	*	–	230	*	–	–	–	*	*	170	2.6	*3.2
#1	26/8/82	G	5.80	1085	0.249	57.5	1,100,000	0.20	2000	–	1.0	–	–	110	1.3	–	–	–	24	120	58	4.8	*25
#3	28/8/82	G	5.63	1090	0.231	56.4	1,100,000	0.26	2000	–	2.9	–	–	130	1.1	–	–	–	14	250	13	5.3	*21
Shell Jumping Pound Preliminary	01/9/82	G	3.33	1160	0.203	154.9	230,000	0.40	63	–	28	15	0.8	230	–	7.9	17	100	–	58	20	3.3	*8.4
#2	01/9/82	G	3.32	1160	0.194	150.9	230,000	0.40	30	–	0.7	–	7.0	40	–	1.0	7.6	63	1.0	47	18	1.8	*6.1
#3	02/9/82	G	3.33	1160	0.201	155.9	230,000	0.40	27	–	0.6	5.0	3.7	47	–	3.1	8.0	–	1.6	–	33	1.9	*6.9

G = Glass Liner

* = Analyses performed on dilute field solutions - poor detection

*Impinger contents could not be evaporated to dryness at temperature specified by Alberta Stack Sampling Code

Table 5.14 Summary of Emission Rates of Elements Whose Presence was Established at Gulf-Strachan, Canterra-Ram River and Shell-Jumping Pound Gas Plants Using Borosilicate Glass Lined Probes

VI. DISCUSSION OF RESULTS

Precautions were taken during sample collection, recovery and analysis to minimize contamination from equipment and chemicals used in the field and laboratory. Rigorous Pre-Test and Preliminary Field Testing Programs helped to define the extent of the background levels of the elements of interest to be expected in the distilled water and nitric acid and on the filters used during this study.

A. PRE-TEST PROGRAM

Quality control on the demineralized water from the ERCB laboratory in Edmonton, Alberta insured that impinger and wash liquids would not be sources of the metals of interest. Only silver (Ag) had been detected at levels just above Inductively Coupled Argon Plasma (ICAP) spectrometer detection limits. According to Table 5.1 arsenic (As), boron (B), beryllium (Be), cadmium (Cd), copper (Cu), molybdenum (Mo), selenium (Se) and Tin (Sn) were detected in the Baker Instra-Analyzed nitric acid at levels of 1 to 2 times the limit of detection (LOD) values of the ICAP spectrometer. Nickel (Ni) appeared to be present, in one sample, at a concentration approaching 3 times the LOD level. Apparent ICAP interferences handicapped the establishment of a realistic antimony (Sb) level in the stock nitric acid.

Selection of quartz microfibre filter material was based on rigorous examination of filter qualities using ICAP analysis. The results of this investigation showed that detectable background levels of silver (Ag), aluminum (Al), arsenic (As), boron (B), iron (Fe), and zinc (Zn) might be expected from filter to filter. Analysis of liquids used to wash the different parts of a sampling train after it had been assembled in the laboratory suggested that background contamination could occur from arsenic (As), cobalt (Co), copper (Cu), iron (Fe), mercury (Hg), nickel (Ni), selenium (Se), tin (Sn), tellurium (Te), and thallium (Tl). Interference problems were always experienced with antimony (Sb) during the ICAP analyses.

B. PRELIMINARY TESTING AT THE RAM RIVER PLANT

Interlaboratory comparisons were carred out on split samples of the filter, impinger and cold trap solutions as well as the probe and nozzle wash from the preliminary test at the Canterra-Ram River Gas Plant.

1. Examination of Filter

The dark deposit on the filter from the preliminary test at the Ram River Gas Plant generated concerns with respect to emissions of organic compounds of the polynuclear aromatic family. However, no evidence for the presence of any single ring or polycyclic organics was established by high performance liquid chromatographic (HPLC) analysis of methylene chloride used to extract a section of this filter. Scanning electron microscopy/energy-dispersive spectrometry (SEM/EDS) indicated that the blackish deposit contained significant proportions of calcium (Ca), magnesium (Mg), silicon (Si) and sulfur (S) with traces of aluminum (Al), chromium (Cr), iron (Fe) and titanium (Ti).

Independent neutron activation analysis (NAA) techniques at the University of Toronto(31) failed to distinguish any significant differences between a blank and a segment of the filter from the preliminary Ram River test.

Atomic absorption (AA) analysis of nitric and hydrochloric acid solutions used to leach 1/4 segments of the preliminary test filter identified the presence of only iron (Fe) and zinc (Zn) while similar treatment of a blank filter showed contamination by aluminum (Al), chromium (Cr) and zinc (Zn).

2. Examination of Impinger Solutions

Neutron activation analysis (NAA) showed that the straw-colored impinger solutions from the preliminary Ram River test contained significant amounts of aluminum (Al), calcium (Ca), sodium (Na), titanium (Ti) and sulfur (S). Small amounts of manganese (Mn) were also found.

Only zinc (Zn) could be detected by atomic absorption (AA) techniques in the original field impinger liquids.

3. Examination of Probe and Nozzle Wash

Measurable levels of aluminum (Al), copper (Cu), manganese (Mn), sodium (Na), and titanium (Ti) were established in the liquid used to wash the probe and nozzle after the preliminary test at the Ram River Gas Plant. However, no sulfur (S) could be detected with the NAA procedures. Atomic absorption (AA) analysis of aliquots of the dilute field washings indicated the presence of only iron (Fe) and zinc (Zn).

4. Development of Plant Testing Program

Preliminary field testing at the Canterra-Ram River Gas Plant indicated that in addition to the 29 metals of interest to this study, significant amounts of calcium (Ca), magnesium (Mg), silicon (Si), and sodium (Na) could be collected during any incinerator stack test. High levels of sulfur (S) could also be expected in the gases exhausted from incinerator stacks.

On the basis of the pre-sampling investigation, it was apparent that field blanks and liquids recovered from impingers and cold traps as well as probe and nozzle washes would require adequate pre-concentration if meaningful results were to be obtained using AA techniques.

C. PLANT TESTS

Recoveries of metals from spiked filter and liquid samples were acceptable during each analytical period. The occasional above average recovery of aluminum (Al), arsenic (As), boron (B), strontium (Sr) and vanadium (V) from spiked filters and liquids was probably due to the interferences and matrix effects created as a result of the complexity of the synthetic solutions generated in the laboratory. It must be appreciated that field liquids never contained all 29 elements simultaneously. Since above average recoveries occurred sporadically, no corrections could be made to measured metal concentrations in any of the liquids analyzed by atomic absorption (AA) procedures.

1. Gulf-Strachan Gas Plant

The presence of aluminum, arsenic, cadmium, chromium, copper, iron, lithium, nickel, lead, titanium and zinc was "established" in the gases exhausted from the incinerator stack at the Gulf-Strachan Gas Plant. Manganese, molybdenum, strontium, tellurium and thallium were "detected" once out of two tests at concentrations just above detection limits as shown in Figure 5.1.

2. Canterra-Ram River Gas Plant

Aluminum, cadmium, iron, lithium, strontium, titanium and zinc were "consistently present" in the gases exhausted from the incinerator stack. Verification of the presence of arsenic, chromium, copper, manganese, molybdenum, lead and tin was handicapped since poor detection limits prevailed during analysis of dilute preliminary test liquids. Their "detection" in one out of two tests suggests that unsteady state operation of the plant, uncertainty of analysis near LOD concentrations or both phenomena could be responsible for the variations.

3. Shell-Jumping Pound Gas Plant

Significant levels of aluminum, cadmium, copper, chromium, iron, manganese, nickel, lead, strontium, titanium and zinc were "established" in the Jumping Pound incinerator stack gases. The sporadic "detection" of arsenic (1 out of 3 tests), antimony (1 out of 3) and tin (1 out of 3) at levels just above the detection limits, as shown in Figure 5.3, suggests that conditions in the plant were not steady throughout the test period.

4. Sources of Aluminum, Copper, Iron, Titanium and Zinc

Discussions with operators after the public peer review (37) suggested that no copper equipment, lines or valves are used in sour gas plants. The presence of copper in the stack gases due to plant construction materials cannot be explained until the inplant sampling study (38) is completed. On the basis of the presently available evidence it must be concluded that copper may be introduced into the system with the entering raw sour gas stream. Significant proportions of the aluminum, iron, titanium and zinc found in the stack gases may be evidence of equipment deterioration as a result of normal corrosion and erosion. Potential in-plant sources of aluminum are refractory linings and the alumina sulfur conversion catalyst used in the Claus process. Titanium might also be a component of refractory linings. The presence of zinc is more difficult to explain at this time. It is possible that zinc anodes used in corrosion control contaminate process streams and/or zinc enters the plant in the raw gas feed stream (35).

D. TOTAL PARTICULATE MATTER EMISSIONS

A source test conducted to determine particulate matter emission rates shall include two emission values:(11)

1) the first emission rate based on the amount of particulate catch in the front-half of the train (in nozzle, probe and filter); and

2) the second emission rate which is based on the total of filtered material in item (1) above plus any particulate matter collected in the impinger solutions.

An examination of Table 5.14 shows that the sums of all the pure metal emissions constitute 1.5 to 24% of the sampling train front-half emission rates. It is not surprising that the pure metals constitute such a small fraction of the front-half emission rate since they are probably emitted in their oxide, sulfate or in part as silicate forms whose formula weights are approximately 2 to 4 times higher than those of the pure metals. In addition, accounting for the presence of silicon (Si), calcium (Ca), potassium (K), sodium (Na) and magnesium (Mg) in stack emissions would significantly improve the agreement between the elemental and front-half emission rates. Differences between pure metal and front-half emission rates can be created by collection of sulfur (S) in the probe and nozzle as well as on the filter.

A reliable estimate of the total particulate catch in the impinger solutions could not be made since these liquids could not be evaporated to dryness at 100 °C as prescribed by AERM(11). Instead of a dry residue, an oily liquid, probably sulfuric acid, remained no matter how long drying was carried out at 100 °C. The sulfuric acid was generated when sulfur dioxide (SO_2) was absorbed by the 6M nitric acid impinger solutions. In addition, some sulfuric acid may arise from trace emissions of SO_3 from the Claus Units. It was impossible to define a constant final weight since sample weights increased during the weighing process as water from the ambient air was absorbed. Consequently the total emission rate is grossly overestimated following the specified procedures(11).

Two explanations were advanced, for the identification of sulfur (S) in various parts of the sampling train after the preliminary test at the Ram River Gas Plant, by scientists attending the seminar organized by the Calgary Section of the Chemical Institute of

Canada (39). It was suggested by one member of the audience that the dark coloring of the residue on the filter was consistent with the collection of nitrogen-sulfur compounds (40). Bett and Winkler (41) have shown that under different experimental conditions the reaction of active nitrogen, (generated by an electrical discharge), with sulfur vapor will produce a blue material with a metallic appearance or a brownish solid. Although the chemistry of nitrogen-sulfur compounds has attracted much recent interest (42, 43) there are no studies that would substantiate the generation of such species in sour gas plant incinerators or other combustion processes.

A more realistic interpretation was provided by members of Alberta Sulphur Research Limited (44). It was suggested that the dark deposit could be "Carsul" which is a well recognized material containing carbon and sulfur. The formation of "Carsul" in the Claus production of sulfur by the reaction of hydrocarbon inpurities in the acid gas feed stream with the product sulfur has been discussed in detail by Hyne (45, 46). Examinations of sulfur stock piles show layers of dark materials that could be produced as a result of plant up-set conditions.

E. COMPARISON OF PLANT OPERATIONS

Sulfur dioxide concentrations in the Gulf-Strachan and Shell-Jumping Pound Gas Plant incinerator stack gases are approximately one and a half to two times higher than those measured at the Canterra-Ram River facility. The lower levels at the Ram River Plant are achieved by processing the gas streams leaving the Claus Sulfur Units in the Sulfreen reactors to insure that total sulfur extraction from the raw gases is over 98%.

Table 6.1 shows that, with very few exceptions, the concentrations of the metals whose presence was "established" definitely in the Gulf-Strachan, Canterra-Ram River and Shell-Jumping Pound Gas Plant incinerator stack gases are of the same order of magnitude. There do not appear to be any well defined trends with respect to emission rates of the metals whose presence was established in the incinerator stack gases at the three plants under investigation.

The metal concentrations and related emission rates corresponding to the preliminary test at the Shell-Jumping Pound plant are considerably higher than the values reported for Tests #2 and #3. These results are consistent with observations made in the field when sample recovery had been completed after each test. Visual inspection of liquid samples showed a high density of shiny flecks dispersed throughout the probe and nozzle wash from only the Preliminary Test. Apparently plant operating conditions were altered for subsequent tests. The wide spreads in the average concentration and emission rate data for the three Jumping Pound tests reflect the variability in plant operating conditions.

Metal	Gulf-Strachan Volumetric Flowrate 230,000 ± 0 acfm*		Canterra-Ram River Volumetric Flowrate 1,070,000 ± 57,000 acfm		Shell-Jumping Pound Volumetric Flowrate 223,300 ± 5,700 acfm	
	Average Concentration ug/rcf**	Average Emission Rate g/h	Average Concentration ug/rcf	Average Emission Rate g/h	Average Concentration ug/rcf	Average Emission Rate g/h
	(Arithmetic Means With Standard Deviations)					
Aluminum	54 ± 21	240 ± 85	125 ± 35	2400 ± 560	11 ± 6	40 ± 20
Arsenic	0.05 ± 0.01	0.21 ± 0.02	---	---	---	---
Cadmium	0.16 ± 0.08	0.69 ± 0.32	0.18 ± 0.04	3.4 ± 0.6	3.5 ± 5.7	13 ± 22
Chromium	1.5 ± 0	6.6 ± 0.1	---	---	2.3 ± 1.4	9.0 ± 5.2
Copper	3.3 ± 3.8	14 ± 17	---	---	1.7 ± 0.7	6.5 ± 2.6
Iron	8.7 ± 3.3	39 ± 15	6.3 ± 1.1	120 ± 14	27 ± 28	102 ± 100
Lithium	0.16 ± 0.04	0.69 ± 0.15	0.17 ± 0.01	3.2 ± 0.1	---	---
Manganese	---	---	---	---	1.3 ± 0.7	4.9 ± 2.6
Nickel	1.5 ± 0	6.6 ± 0.1	---	---	4.6 ± 4.5	18 ± 17
Lead	2.3 ± 0.1	9.9 ± 0.1	---	---	11 ± 15	37 ± 54
Strontium	---	---	1.0 ± 0.4	19 ± 7	0.51 ± 0.18	2.0 ± 0.7
Titanium	13 ± 3	59 ± 9	15 ± 2	285 ± 49	12 ± 4	45 ± 15
Zinc	6.5 ± 2.6	29 ± 11	2.4 ± 0.9	46 ± 18	6.0 ± 1.4	23 ± 5

* acfm = Actual cubic feet per minute at stack temperature and pressure

** rcf = Reference cubic feet at 25° C and 1 atmosphere

Table 6.1 Comparison of Average Concentrations and Emission Rates of Metals Found in the Gulf-Strachan, Canterra-Ram River and Shell-Jumping Pound Gas Plant Incinerator Stacks

F. RANDOM ERROR ANALYSIS

At the conclusion of the entire trace element emission study a comprehensive error analysis will be developed to establish a random error limits on the total and elemental emission rates due to:

i. equipment and personnel variations in field procedures

ii. equipment and personnel variations in the laboratory

VII. CONCLUSIONS AND RECOMMENDATIONS

The presence of aluminum, arsenic, cadmium, chromium, copper, iron, lithium, nickel, lead, titanium and zinc has been established in the incinerator stack gas emissions from the Gulf-Strachan Gas Plant.

Aluminum, cadmium, iron, lithium, strontium, titanium and zinc were established as metals consistently present in the gases exhausted from the Canterra-Ram River Gas Plant incinerator stack.

The gases emitted from the Shell-Jumping Pound Gas Plant incinerator stack carry established levels of aluminum, cadmium, chromium, copper, iron, manganese, nickel, lead, strontium, titanium and zinc.

The nature and amounts of the elements released into the atmosphere do not appear to create critical emission problems in the areas surrounding each of the plants under investigation. The impact of the incinerator stack emissions on downwind, ambient, ground level concentrations is expected to be minimal. However, short-range atmospheric dispersion modelling of the emissions from each stack is recommended to more accurately assess the deposition on receptors at ground level.

A comprehensive ambient air sampling program in urban and rural areas, where trace element concentrations are projected to be independent of sour gas plant emission, is needed to establish typical background levels in different regions of Alberta. Upwind and downwind sampling of each plant would help to establish the contributions from the incinerator stacks to the atmospheric loadings that affect receptors at ground level. It must be emphasized that any proposed ambient air sampling program requires significant modifications to currently available high-volume samplers to ensure high efficiency capture of sub-micron particulate matter.

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APPENDIX I

GAS CHROMATOGRAPH CALIBRATION GAS ANALYSIS
and
TECHNICAL DATA ON ULTRA-PURE QM-A QUARTZ FILTERS

DB ROBINSON & ASSOCIATES LTD.

9324 · 31 AVENU
EDMONTON, ALBERTA, CANAD
T6N 1C

TELEPHONE (403) 463-863

November 2, 1982

Our File: 11Y-24-82

Energy Resources Conservation Board
640 - Fifth Avenue S.W.
Calgary, Alberta
T2P 3G4

Attention: Dr. H. Thimm

Dear Dr. Thimm,

Re: Analysis of Gas Sample

G.C. Standard

This concerns the analysis of a gas sample picked up from your office in Calgary on October 8th, 1982.

The sample was reported to contain approximately:

	Mole Fraction
N_2	0.945
CO	0.015
CO_2	0.040

Accordingly, a sample of gas containing these materials was prepared by charging known amounts of the pure components into a high pressure sample bomb and obtaining the weights of each component gravimetrically using a Mettler balance having a resolution of 0.0001 g. The composition of this sample was:

	Mole Fraction
N_2	0.8978
CO	0.0158
CO_2	0.0864

Relative response factors for each of the components in the mixture were determined from this primary standard.

The unknown sample was then analyzed using a molecular sieve 5A 60-80 mesh column using temperature programming from 35 to 170°C. During these operations it was determined that the "nitrogen" in the sample was actually air, and additional work had to be done to clarify this problem. The composition of the mixture was calculated to be:

Component	Concentration Mole Fraction	Reliability
O_2	0.1987	±0.0001
N_2	0.7474	±0.0005
CO	0.0141	±0.0001
CO_2	0.0398	±0.0002

If you have any questions about the results, please give us a call. It was a pleasure to be of assistance to you.

Yours very truly,

DB ROBINSON & ASSOCIATES LTD.

D. B. ROBINSON

PRESIDENT

DBR/plr

Whatman PAPER DIVISION

LARRY G. WEST
Technical Services Specialist

Whatman Laboratory Products Inc

9 Bridewell Place, Clifton, NJ 07014
201-773-5800 Telex 133426
A member of the Whatman Reeve Angel Group

TECHNICAL DATA ON
ULTRA-PURE QM-A QUARTZ FILTERS

QM-A QUARTZ TECHNICAL DATA

Basis Weight	85 gm/m²
Thickness	0.45 mm
Particle retention efficiency (0.6 μm particles at 5cm/sec F.V.)	99.999% retention or 0.001% penetration
Dry Tensile (1.5 cm wide strip)	250 – 300 g
Maximum Temperature	500° C
Air flow rate (for 400 cm² filter area at Δ p = 20 mm Hg)	800 litres/min

N.B. 400 cm² is effective filtration area of 8'' x 10'' sheet

CHEMICAL PURITY

Element	p.p.m.	Micrograms per sheet (8 x 10 in)
Cd	0.23	1
Co	1.1	5
Cr	1.6	7
Cu	3.4	15
Fe	23.0	100
Mn	0.46	2
Ni	3.4	15
Pb	2.3	10
Zn	18.2	80

All values typical subject to normal manufacturing tolerances.

QM-A. THE NEW ULTRA-PURE QUARTZ FILTER FROM WHATMAN FOR AIR SAMPLING.

Whatman now introduce QM-A, an ultra-pure quartz (SiO_2) microfibre filter for the most exacting work in air pollution monitoring. QM-A is heat-treated and entirely binder free and only a small amount (5%) of conventional borosilicate glass microfibres are added for papermaking purposes.

ULTRA-PURE – HIGH FLOW RATES

Ultra-pure QM-A is extremely low in heavy metal content, whilst offering the high flow rates and filtration efficiencies of conventional borosilicate glass microfibre filters. Trace level determinations in particulates can now be carried out with the utmost accuracy.

LOW IN ALKALINE EARTH METALS

Whatman QM-A contains virtually no alkaline earth metals and is therefore recommended for sampling and subsequent analysis of environments where acidic gases such as SO_2 and NO_2 are encountered. 'Artifact' production of sulphates and nitrates on the filter, is, thus, virtually eliminated with QM-A and critical analyses can now be conducted free from inaccuracies caused by artifact production with glass microfibre filters.

APPLICATIONS

Whatman QM-A is suitable for ambient and high temperature (max 500° C) air sampling of environments such as stacks, flue outlets and aerosols. Being ultrapure and containing low levels of elements important in pollution studies, Whatman QM-A is the filter of choice for critical analyses and trace level determinations, and it is especially suitable for analytical techniques such as atomic absorption spectroscopy and flame emission spectrophotometry.
The low background levels of heavy metals in QM-A also make it suitable for X-ray fluorescence techniques and neutron activation analyses

MINIMAL WEIGHT LOSS

QM-A is heat treated after manufacture to remove bound moisture and trace organic impurities and to ensure minimal weight loss on further heating. For accurate gravimetric results, as with any medium, it is essential, both before and after sampling, to condition the filter carefully before weighing.

AVAILABILITY

Standard Sizes		Cat. No.
Circles:	3.2 cm dia	1851 032
	3.7	1851 037
	4.7	1851 047
	5.5	1851 055
Sheets:	20.4 x 25.4 cm (8 x 10 in)	1851 865

PUBLICATION NO 860 QM-A A

QM-A QUARTZ ULTRA-PURE FILTERS DATA SHEET 860 QM-A A

COMPARISON OF PHYSICAL CHARACTERISTICS AND CHEMICAL PURITY OF WHATMAN QM-A QUARTZ MICROFIBRE FILTERS, EPM1000, GF/A AND GRADE 41

(1) PHYSICAL CHARACTERISTICS:

	QM-A	EPM1000	GF/A	No. 41
Composition	Quartz Microfibre	Glass Microfibre	Glass Microfibre	Cellulose (Cotton Linters)
Basis weight	85	80	53	85
Thickness (mm)	0.45	0.43	0.26	0.21
Dry Tensile[2] (g)	250-300	742	430	2400
Sodium Flame Retention[3] (Nafla) (%)	99.999	99.999	99.995	74
ΔP[4] (mm Hg)	3	3	3	3
Temperature Resistance (Max. °C)	500	500	500	200
Air[5] Flow Rate at ΔP = 3	120	120	120	120
Air[5] Flow Rate at ΔP = 20	800	750	950	1150

NOTES

[1] All values are 'typical' and subject to normal manufacturing tolerances.

[2] Tensile 1.5 cm wide strip.

[3] Sodium flame penetrometer to BS 4400 all values at 5cms/Sec F.V.

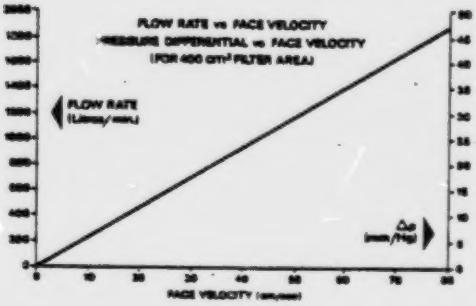
[4] Pressure differential across filter at 5cms/Sec F.V.

[5] Measured in litre/minute for air (values for 400 cm² area assuming no flow restriction imposed by holder).

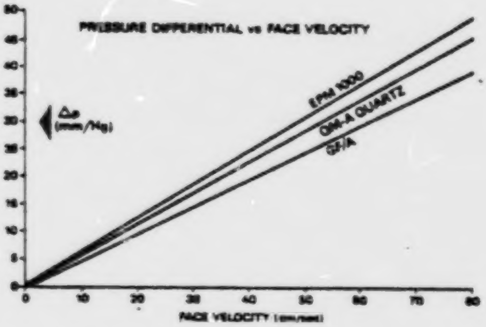
Key F.V. = Face Velocity

NB ΔP figures at higher FV's than 5 cms/sec vary considerably with grade of filter – see Air Pollution Monitoring brochure for graphs of ΔP vs F.V.

QM-A QUARTZ FILTER FLOW RATE



COMPARISON OF QM-A QUARTZ, EPM1000 AND GF/A



(2) CHEMICAL PURITY Concentrations given in µg/sheet (8" x 10") and in p.p.m.

	QM-A		EPM1000		GF/A		GRADE 41	
Element	µg/sheet	p.p.m.	µg/sheet	p.p.m.	µg/sheet	p.p.m.	µg/sheet	p.p.m.
Cd	1.0	0.23	2.1	0.5	2.7	1.0	ND	ND
Co	4.8	1.1	1.24	0.3	2.7	1.0	ND	ND
Cr	7.0	1.6	4.95	1.2	0.55	0.2	1.3	0.3
Cu	14.9	3.4	2.9	0.7	16.4	6.0	1.75	0.4
Fe	100	23	103	25	275	100	26.3	6.0
Mn	2.0	0.46	4.95	1.2	21.9	8.0	<0.22	<.05
Ni	14.9	3.4	14.4	3.5	16.4	6.0	ND	ND
Pb	10.0	2.3	10.3	2.5	27	10	0.9	0.2
Zn	80	18.2	103	25	ND	ND	2.6	0.6

KEY: ND = NOT DETERMINED

NOTES Cellulose Data obtained from analysis of ash. Glass Data obtained from extraction under acid conditions.

Whatman

PAPER DIVISION

Whatman Laboratory Products Inc 9 Bridewell Place, Clifton, New Jersey 07014 USA Tel: (201) 773-5800 Sales Tel: (201) 777-4825 Telex: 133426

APPENDIX II

PREPARATION OF DEMINERALIZED WATER
and
ACTUAL LOT ANALYSIS (218042)
for
BAKER INSTRA-ANALYZED NITRIC ACID

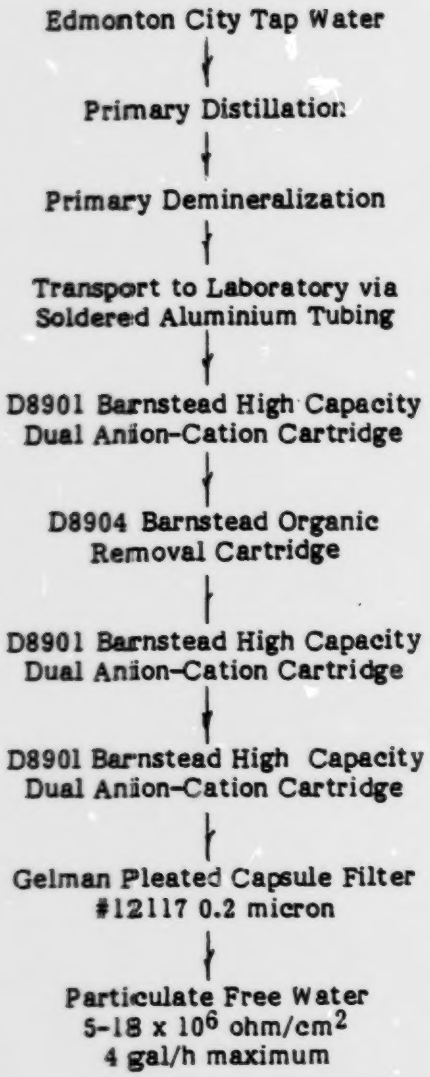

Edmonton City Tap Water
Primary Distillation
Primary Demineralization
Transport to Laboratory via Soldered Aluminium Tubing
D8901 Barnstead High Capacity Dual Anion-Cation Cartridge
D8904 Barnstead Organic Removal Cartridge
D8901 Barnstead High Capacity Dual Anion-Cation Cartridge
D8901 Barnstead High Capacity Dual Anion-Cation Cartridge
Gelman Pleated Capsule Filter #12117 0.2 micron
Particulate Free Water
5-18 x 10^6 ohm/cm^2
4 gal/h maximum

Figure II.1 Preparation of Demineralized Water by Energy Resources Conservation Board Laboratory, Edmonton, Alberta

APPENDIX II

Assay (HNO_3) (by acid base titration)	70.3%
Appearance	Passes test
Color (APHA)	< 5
Density at 20°C	1.426 gm/ml
Residue after ignition	2 ppm

Trace Impurities (ppm) (µg/g)

Chloride (Cl)	< 0.08	Lead (Pb)	0.0002
Phosphate (PO_4)	< 0.1	Lithium (li)	< 0.02
Sulphate (SO_4)	< 0.5	Magnesium (Mg)	0.02
Aluminum (Al)	0.05	Manganese (Mn)	0.0004
Arsenic and Antimony (as As)	< 0.005	Mercury (Hg)	< 0.0001
Barium (Ba)	< 0.02	Nickel (Ni)	0.003
Boron (B)	0.001	Potassium (K)	< 0.1
Cadmium (Cd)	< 0.002	Silicon (Si)	0.01
Calcium (Ca)	0.02	Silver (Ag)	< 0.0001
Chromium (Cr)	0.02	Sodium (Na)	0.2
Cobalt (Co)	0.0002	Strontium (Sr)	< 0.002
Copper (Cu)	0.0003	Tin (Sn)	0.001
Heavy Metals (as Pb)	0.05	Zinc (Zn)	< 0.002
Iron (Fe)	0.02		

Table II.1 Actual Lot Analysis (218042) for Baker Instra-Analyzed Nitric Acid

APPENDIX III

INDUCTIVELY COUPLED ARGON PLASMA SPECTROMETER SPECIFICATIONS

CP (INDUCTIVELY COUPLED PLASMA SPECTROMETER)

Manufacturer:	Applied Research Laboratories Dearborn, Michigan
Model No.	35,000

The 35,000 ICP is an automated liquids analysis instrument for either precise quantitative elemental analysis, or for qualitative elemental purposes.

Specifications

Monocromator - Air Version

Czerny Turner Mounting, High Precision Bausch & Lomb Diffraction Grating

Focal Length 1.0 meter

Blazed At 1200 l/mm

Spectral Range 1900 - 8800 Angstroms (1st order)

Dispersion 8 Angstroms/mm

Width of Primary and Secondary Slit 20/um

Unit is Equipped with an Oxidation Gaseous Hydride Module

High Frequency Generator

Connected to ICP stand by a flexible cable

Operating frequency: 27.12 MHz, quartz stabilized

Maximum power: 2.5 kW

Automatic power regulation

Air cooled

A hot-air exhaust for the stand and for the generator

System Controlled Autosampler

Permits automatic introduction of samples and allows efficient operation by eliminating human error. Contributes to reproducibility and general quality of results while freeing the analyst for more productive activity.

Package consists of an automatic sample changer with capacity for up to 24 sample or rinse containers. Integrated into the 35000 work table. With control circuitry and software compatible with ICP-User's programs and ARL Extended Basic.

APPENDIX IV

FIELD SAMPLING DATA and ELEMENTAL EMISSION RATES

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: STRACHAN

COMPANY: GULF

2) TEST NO: Preliminary DATE: August 21, 1982

3) PRODUCTION: 2.35×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.95 (inches Hg)

STATIC PRESSURE: -2.2 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 15 8/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.885

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.50 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 3.85, O_2 13.64, CO 0.77

SO_2 0.23, N_2 80.55, Ar 0.96

7) NO. OF READINGS:

TIME BETWEEN READINGS: 2 min.

TEST POINTS/TRAVERSE: 8

NO. OF TRAVERSES: 3

8) CONDENSED WATER: 210.0 (grams)

WATER CAUGHT BY DRYING AGENTS: 12.3 (grams)

MOISTURE CONTENT, B_{wo}: 0.144

9) MOLECULAR WEIGHT OF GAS:

29.36 DRY BASIS (lb_m/lb mole)

27.72 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 71.99 (acf)

11) AVERAGE STACK VELOCITY: 22.41 (ft/s) AVG.TEMP.: 960 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 260,000 (acfm)

Table IV.1 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	980	0.04	21.44	0.62	864.67	280	235	70	70	75	75	2.00	0.00
1	2	980	0.04	21.44	0.62	865.94	240	235	70	70	77	75	2.00	91.39
1	5	945	0.04	21.70	0.65	867.36	240	235	70	85	77	80	2.00	98.38
2	7	945	0.04	21.70	0.65	868.91	240	235	65	105	78	80	2.00	107.73
2	10	950	0.04	21.73	0.65	870.37	240	235	65	120	78	80	2.00	100.95
3	12	950	0.05	22.75	0.73	871.82	240	240	60	140	80	80	2.00	96.06
3	15	950	0.05	22.75	0.73	873.45	240	240	60	140	80	80	2.00	107.86
4	17	940	0.04	21.14	0.64	874.91	280	245	55	115	80	82	1.50	102.52
4	20	940	0.04	21.14	0.64	876.39	280	245	55	115	80	82	1.80	104.38
5	22	940	0.05	22.42	0.72	877.95	280	250	55	115	80	85	2.00	103.50
5	25	940	0.05	22.42	0.72	879.48	280	250	55	115	80	85	2.00	101.54
6	27	950	0.05	23.71	0.80	881.03	280	250	55	115	82	86	3.00	97.72
6	30	950	0.05	22.50	0.72	882.43	280	250	55	120	82	88	2.00	92.46
7	32	955	0.05	22.54	0.72	883.87	280	255	55	120	85	90	2.00	95.19
7	35	955	0.05	22.54	0.72	885.37	280	255	55	120	85	90	2.00	98.94
8	37	955	0.05	22.54	0.72	886.83	280	255	55	120	85	90	2.00	96.91
8	40	955	0.05	22.54	0.72	888.21	280	255	55	120	85	90	2.00	90.93

Table IV.2 : Field Sampling Data for Preliminary Survey, Gulf - Strachan, Traverse #1, August 21, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	950	0.05	22.50	0.72	888.21	280	255	55	120	85	90	2.00	0.00
1	2	950	0.05	22.50	0.72	889.63	280	255	55	120	85	90	2.00	93.36
1	5	950	0.05	22.50	0.72	891.17	280	255	55	120	85	90	2.00	101.68
2	7	950	0.05	22.50	0.72	892.83	278	255	55	120	85	90	2.00	109.93
2	10	950	0.05	22.50	0.72	894.42	278	255	55	120	85	90	2.00	104.34
3	12	960	0.04	22.07	0.69	895.85	278	260	55	120	86	90	2.00	96.64
3	15	960	0.04	22.07	0.69	897.34	278	260	55	120	86	90	2.00	100.77
4	17	960	0.05	23.80	0.80	898.85	280	250	55	120	88	91	2.50	94.76
4	20	960	0.05	23.80	0.80	900.47	280	250	55	120	88	91	2.50	101.64
5	22	970	0.05	22.66	0.72	901.94	280	255	55	120	89	91	2.00	96.90
5	25	970	0.05	22.66	0.72	903.55	280	255	55	120	89	91	2.00	106.65
6	27	975	0.05	22.70	0.71	905.18	280	255	59	118	89	91	2.00	107.82
6	30	975	0.05	22.70	0.71	906.80	280	255	59	118	89	91	2.00	107.01
7	32	960	0.05	22.58	0.71	908.19	280	255	58	118	89	91	2.00	91.72
7	35	960	0.05	22.58	0.71	909.82	280	255	58	118	89	91	2.00	107.17
8	37	970	0.05	22.66	0.71	911.30	280	260	60	119	90	91	2.00	97.63
8	40	970	0.05	22.66	0.71	912.83	280	260	60	119	90	91	2.00	101.13

Table IV.3 : Field Sampling Data for Preliminary Survey, Gulf - Strachan, Traverse #2, August 21, 1982

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD
LOCATION: STRACHAN
COMPANY: GULF

2) TEST NO: 1 DATE: August 22, 1982

3) PRODUCTION: 1.84×10^6 m^3/da, Plant Sales

4) BAROMETRIC PRESSURE: 25.95 (inches Hg)
STATIC PRESSURE: -2.2 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D) 15 8/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.885
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 0.50 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 3.85, O_2 13.64, CO 0.77
SO_2 0.23, N_2 80.55, Ar 0.96

7) NO. OF READINGS: 48
TIME BETWEEN READINGS: 4 min.
TEST POINTS/TRAVERSE: 8
NO. OF TRAVERSES: 3

8) CONDENSED WATER: 231.8 (grams)
WATER CAUGHT BY DRYING AGENTS: 14.8 (grams)
MOISTURE CONTENT, B_{wo}: 0.129

9) MOLECULAR WEIGHT OF GAS:
29.36 DRY BASIS (lb_m/lb mole)
27.89 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 90.67 (acf)

11) AVERAGE STACK VELOCITY: 17.94 (ft/s) AVG.TEMP: 950 (°F)
AVERAGE VOLUMETRIC FLOW RATE: 210,000 (acfm)

Table IV.4 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	950	0.05	22.50	0.72	912.83	280	255	55	120	85	90	2.00	0.00
1	2	950	0.05	22.50	0.72	914.47	280	255	55	120	85	90	2.00	108.09
1	5	950	0.05	22.50	0.72	915.96	280	255	55	120	85	90	2.00	98.32
2	7	950	0.05	22.50	0.72	917.43	278	255	55	120	85	90	2.00	97.09
2	10	950	0.05	22.50	0.72	918.91	278	255	55	120	85	90	2.00	97.63
3	12	960	0.04	22.07	0.69	920.27	278	260	55	120	86	90	2.00	91.88
3	15	960	0.04	22.07	0.69	921.64	278	260	55	120	86	90	2.00	92.68
4	17	960	0.05	23.80	0.80	923.38	280	250	55	120	88	91	2.50	109.00
4	20	960	0.05	23.80	0.80	924.98	280	250	55	120	88	91	2.50	99.90
5	22	985	0.05	22.78	0.71	926.46	280	260	60	117	88	91	2.00	98.32
5	25	985	0.05	22.78	0.71	927.82	280	260	60	117	88	91	2.00	90.84
6	27	985	0.05	22.78	0.71	929.33	280	260	60	120	88	91	2.00	100.12
6	30	965	0.05	22.62	0.71	930.89	280	260	60	120	88	91	2.00	103.23
7	32	960	0.04	21.29	0.63	932.30	280	255	60	118	88	91	1.50	98.27
7	35	960	0.04	21.29	0.63	933.73	280	255	60	118	88	91	1.50	100.52
8	37	970	0.04	21.36	0.63	935.14	280	255	65	118	88	88	1.50	98.66
8	40	970	0.04	21.36	0.63	936.66	280	255	65	118	88	88	1.50	107.28

Table IV.5 : Field Sampling Data for Preliminary Survey, Gulf - Strachan, Traverse #3, August 21, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	970	0.04	21.27	0.61	57.68	260	240	78	75	72	72	2.00	0.00
1	4	970	0.04	21.27	0.61	59.73	260	240	78	75	72	72	2.00	91.46
1	8	960	0.04	21.72	0.61	62.01	250	240	68	97	75	75	2.00	98.75
2	12	950	0.05	24.77	0.84	64.92	250	240	60	110	75	77	2.50	109.39
2	16	960	0.06	25.96	0.92	67.92	240	240	57	120	78	80	3.00	107.55
3	20	960	0.05	22.48	0.70	70.35	240	240	57	125	78	80	2.20	100.79
3	24	965	0.04	20.69	0.59	72.49	235	255	57	145	78	80	2.00	96.86
4	28	970	0.04	21.79	0.61	74.68	238	255	60	140	78	82	2.00	94.00
4	32	960	0.04	20.66	0.59	76.73	240	255	60	150	80	82	2.00	92.26
5	36	965	0.03	18.39	0.46	78.86	240	260	62	148	80	85	2.00	107.59
5	40	955	0.03	18.32	0.46	80.75	240	255	62	140	82	85	2.00	95.15
6	44	955	0.02	16.73	0.39	82.62	240	255	62	140	82	85	2.00	102.62
6	48	957	0.02	16.74	0.39	84.42	240	255	62	140	82	85	2.00	99.30
7	52	960	0.02	14.99	0.31	85.93	255	255	68	140	87	90	2.00	92.28
7	56	960	0.02	14.99	0.31	87.57	255	255	68	140	87	90	2.00	99.96
8	60	980	0.00	6.75	0.06	88.36	260	258	65	125	87	90	1.00	109.19
8	64	980	0.00	6.75	0.06	89.06	260	258	67	162	88	88	1.00	95.52

Table IV. 6 : Field Sampling Data for Test #1, Gulf - Strachan, Traverse #1, August 22, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	970	0.05	22.56	0.69	89.06	238	240	62	62	72	72	2.50	0.00
1	4	920	0.05	22.16	0.69	91.23	270	235	55	100	70	70	2.50	90.45
1	8	920	0.04	20.89	0.63	93.57	270	215	52	120	70	71	2.50	102.99
2	12	920	0.04	20.63	0.62	95.90	270	225	52	130	71	71	2.50	103.91
2	16	960	0.04	20.93	0.60	98.04	270	225	52	130	71	71	2.50	96.50
3	20	915	0.03	18.06	0.46	100.10	275	250	53	140	72	75	1.80	103.84
3	24	915	0.04	19.51	0.54	102.12	275	250	53	140	72	75	1.80	94.52
4	28	950	0.03	18.29	0.46	103.92	270	320	60	105	70	70	1.50	92.53
4	32	960	0.03	18.36	0.46	105.94	270	300	55	165	70	70	1.50	104.50
5	36	940	0.02	14.88	0.31	107.45	270	270	57	160	70	71	1.50	94.23
5	40	940	0.03	18.23	0.46	109.50	270	255	57	150	70	71	1.50	104.85
6	44	940	0.02	14.88	0.31	111.11	270	250	58	155	71	73	1.00	101.00
6	48	940	0.02	14.12	0.28	112.67	275	245	60	140	72	74	1.00	102.34
7	52	940	0.01	12.45	0.22	114.08	275	240	62	140	72	75	1.00	105.07
7	56	940	0.01	11.53	0.19	115.44	275	240	62	140	72	75	1.00	109.33
8	60	945	0.00	4.71	0.03	115.90	275	235	65	125	75	75	1.00	90.37
8	64	935	0.00	5.75	0.05	116.51	275	230	68	95	75	77	1.00	98.22

Table IV 7 : Field Sampling Data for Test #1, Gulf - Strachan, Traverse #2, August 22, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	960	0.05	22.48	0.69	116.51	285	200	62	62	71	71	2.00	0.00
1	4	960	0.05	22.48	0.69	118.79	285	200	62	62	71	71	2.00	95.96
1	8	960	0.05	23.70	0.77	121.10	285	240	55	105	71	74	2.00	91.79
2	12	960	0.05	23.93	0.79	123.82	285	230	55	115	72	75	2.20	107.10
2	16	975	0.06	25.43	0.88	126.40	285	230	55	149	73	77	2.60	96.48
3	20	950	0.05	24.77	0.85	128.92	290	265	55	155	74	77	2.50	94.95
3	24	955	0.05	24.81	0.85	131.62	285	270	56	155	75	78	2.50	101.36
4	28	950	0.05	24.31	0.82	134.07	285	295	55	180	75	79	2.40	93.59
4	32	950	0.05	24.31	0.82	136.93	285	295	55	180	75	79	2.40	109.33
5	36	960	0.05	23.70	0.77	139.31	280	275	57	180	78	80	2.20	93.62
5	40	955	0.03	18.32	0.77	141.23	280	275	57	180	78	80	2.20	97.77
6	44	965	0.02	15.01	0.35	142.91	280	265	58	175	78	80	2.00	104.06
6	48	970	0.02	14.66	0.29	144.54	280	245	58	165	78	81	1.00	104.43
7	52	965	0.02	13.43	0.25	146.12	280	240	60	140	78	80	1.00	109.99
7	56	970	0.01	10.63	0.16	147.26	280	240	62	130	79	81	1.00	100.11
8	60	960	0.00	5.80	0.05	147.83	280	238	62	120	79	80	0.50	90.76
8	64	960	0.00	4.74	0.03	148.35	280	238	62	120	79	80	0.50	103.51

Table IV 8 : Field Sampling Data for Test #1, Gulf - Strachan, Traverse #3, August 22, 1982

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: STRACHAN

COMPANY: GULF

2) TEST NO: 2 DATE: August 23, 1982

3) PRODUCTION: 2.70 x 10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.95 (inches Hg)

STATIC PRESSURE: -1.8 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D)15 8/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.885

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.50 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 6.84, O_2 9.88, CO 0.30

SO_2 0.31, N_2 81.70, Ar 0.97

7) NO. OF READINGS: 48

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 8

NO. OF TRAVERSES: 3

8) CONDENSED WATER: 208.6 (grams)

WATER CAUGHT BY DRYING AGENTS: 9.5 (grams)

MOISTURE CONTENT, B_{wo}: 0.107

9) MOLECULAR WEIGHT OF GAS:

29.72 DRY BASIS (lb_m/lb mole)

28.47 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 99.40 (acf)

11) AVERAGE STACK VELOCITY: 19.54 (ft/s) AVG.TEMP.: 960 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 230,000 (acfm)

Table IV.9 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	960	0.05	22.98	0.74	169.70	235	210	70	72	69	69	2.00	0.00
1	4	960	0.05	22.98	0.74	171.97	235	210	70	72	69	69	2.00	91.50
1	8	955	0.05	22.94	0.74	174.44	235	255	62	138	70	71	2.00	99.01
2	12	970	0.05	23.54	0.77	176.74	235	290	60	155	70	72	2.00	90.54
2	16	960	0.05	23.45	0.77	179.09	235	260	60	165	71	75	2.00	92.16
3	20	960	0.04	20.98	0.62	181.34	235	315	60	175	72	76	1.50	98.10
3	24	960	0.04	21.50	0.65	183.67	235	290	61	180	72	76	2.00	99.15
4	28	960	0.04	20.45	0.59	185.73	235	288	60	178	74	79	1.00	92.02
4	32	955	0.04	20.94	0.63	188.03	235	280	62	172	75	80	1.00	99.78
5	36	955	0.04	19.59	0.55	189.99	235	280	62	172	75	80	1.00	90.45
5	40	955	0.03	18.73	0.50	192.15	235	270	61	152	77	81	1.00	104.68
6	44	962	0.03	18.18	0.47	194.04	235	265	61	145	78	81	1.00	94.03
6	48	960	0.02	15.56	0.35	195.79	235	265	62	138	78	81	0.75	102.09
7	52	950	0.02	14.78	0.31	197.54	235	262	62	125	78	81	0.50	106.24
7	56	960	0.02	13.27	0.25	198.98	235	262	65	125	78	81	0.50	98.66
8	60	960	0.01	10.49	0.16	200.09	235	260	65	112	78	81	0.50	95.77
8	64	960	0.01	10.49	0.16	201.33	235	260	65	112	78	81	0.50	106.73

Table IV.10 : Field Sampling Data for Test #2, Gulf - Strachan, Traverse #1,, August 23, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	960	0.04	21.24	0.63	201.33	235	200	60	60	69	70	2.00	0.00
1	4	960	0.04	21.24	0.63	203.59	235	200	60	60	69	70	2.00	98.41
1	8	960	0.05	22.25	0.69	206.24	235	200	55	110	70	70	2.00	109.90
2	12	960	0.05	22.25	0.69	208.50	235	215	55	110	70	71	2.00	93.69
2	16	960	0.05	22.25	0.69	210.74	235	215	55	110	70	71	2.00	93.01
3	20	970	0.04	19.69	0.54	212.75	235	285	52	135	69	72	1.50	94.88
3	24	970	0.05	22.82	0.72	215.02	235	280	50	142	70	72	2.00	92.14
4	28	970	0.04	21.05	0.62	217.27	235	260	52	150	70	74	1.00	98.97
4	32	970	0.05	22.33	0.69	219.79	235	260	52	150	70	74	1.00	104.51
5	36	960	0.04	20.98	0.62	221.99	235	252	55	165	71	76	1.50	96.36
5	40	970	0.04	21.05	0.62	224.22	235	255	56	151	71	77	1.50	97.59
6	44	965	0.03	18.20	0.46	226.16	235	250	55	148	72	77	1.00	98.22
6	48	970	0.03	17.61	0.43	227.91	235	255	57	150	72	77	1.00	91.07
7	52	960	0.02	14.83	0.31	229.57	235	250	57	149	72	77	0.50	102.41
7	56	960	0.02	14.83	0.31	231.11	235	250	57	149	72	77	0.50	94.84
8	60	970	0.01	10.53	0.15	232.33	235	255	58	132	72	77	0.50	107.29
8	64	970	0.01	10.53	0.15	233.36	235	255	58	132	72	77	0.50	90.18

Table IV.11 : Field Sampling Data for Test #2,,Gulf - Strachan, Traverse #2, August 23, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	975	0.05	23.58	0.77	233.36	230	240	68	68	72	72	2.20	0.00
1	4	975	0.05	23.58	0.77	235.78	230	240	68	68	72	72	2.20	95.47
1	8	985	0.05	23.66	0.77	238.34	240	250	58	120	72	72	2.20	101.22
2	12	975	0.05	22.61	0.70	240.97	235	250	55	130	72	72	2.10	108.11
2	16	975	0.05	22.37	0.69	243.32	235	230	55	130	72	73	2.20	97.68
3	20	965	0.04	21.53	0.64	245.50	235	215	55	135	72	74	2.20	93.09
3	24	970	0.04	21.05	0.61	247.77	235	225	55	140	72	76	2.20	99.43
4	28	965	0.04	19.66	0.54	249.89	235	230	56	145	74	78	2.30	98.80
4	32	970	0.05	22.57	0.70	252.30	235	235	58	145	75	79	1.80	97.93
5	36	965	0.04	21.53	0.64	254.62	235	240	55	150	76	80	2.40	98.33
5	40	965	0.04	21.53	0.64	257.18	238	245	59	152	76	81	2.10	108.63
6	44	975	0.04	21.09	0.61	259.65	238	250	58	155	78	82	2.10	106.81
6	48	965	0.04	21.01	0.61	262.04	238	255	60	160	80	82	1.90	103.26
7	52	970	0.03	18.23	0.46	264.00	235	245	61	160	80	83	1.80	98.19
7	56	965	0.03	18.20	0.46	266.01	240	245	60	155	82	84	1.50	99.82
8	60	970	0.02	14.89	0.31	267.58	240	245	62	158	82	84	1.50	95.20
8	64	965	0.02	14.86	0.31	269.10	235	245	67	150	82	84	1.20	92.85

Table IV.12 : Field Sampling Data for Test #2, Gulf - Strachan, Traverse #3, August 23, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	950	0.05	22.54	0.69	278.89	235	220	62	62	63	63	2.00	0.00
1	4	950	0.05	22.54	0.69	280.98	235	225	62	62	63	63	2.00	92.06
1	8	940	0.05	23.67	0.77	283.45	267	225	55	135	65	67	2.20	102.41
2	12	940	0.05	23.19	0.74	285.96	275	235	55	145	69	70	2.10	105.86
2	16	940	0.05	22.46	0.69	288.12	235	240	55	145	69	71	2.00	93.46
3	20	940	0.04	21.95	0.66	290.56	230	245	55	150	70	74	2.00	107.98
3	24	940	0.04	21.95	0.66	292.98	230	245	55	150	70	74	2.00	106.75
4	28	945	0.04	21.21	0.61	295.36	230	255	55	155	74	76	1.00	108.64
4	32	945	0.04	21.21	0.61	297.36	230	260	55	160	75	78	1.00	91.03
5	36	940	0.04	21.17	0.61	299.74	250	260	55	160	75	78	1.00	108.42
5	40	930	0.04	20.56	0.58	301.71	240	265	55	162	75	79	1.00	91.19
6	44	950	0.04	19.88	0.54	303.59	230	270	55	165	76	80	0.70	91.40
6	48	940	0.03	18.34	0.46	305.65	230	270	56	165	78	80	0.50	107.62
7	52	970	0.03	19.14	0.49	307.68	235	272	58	165	79	81	0.50	103.11
7	56	950	0.03	18.09	0.45	309.74	235	275	58	165	79	81	0.50	109.97
8	60	950	0.02	16.80	0.38	311.35	235	275	60	165	79	81	0.50	91.86
8	64	950	0.02	16.80	0.38	313.12	235	275	60	165	79	81	0.50	101.35

Table IV.13 : Field Sampling Data for Test #3, Gulf - Strachan, Traverse #1, August 24, 1982

Sample Analyses	Test No 2		Date August 23, 1982			Strachan	
Sample From	P&W 6N HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/scf	Elemental Emission Rate g/hr
Volume (ml)	345	550	190		$E_R = 3.1 \times 10^4$		kg/d (total)
Total Particulate (mg)	25	19000	-	5.1	$E_R = 5.0 \times 10^1$		kg/d (front end)
Al Aluminum	140	110	95	$\boxed{4000}$	$\boxed{4300}$	$\boxed{69}$	$\boxed{300}$
As Arsenic	$\boxed{1.0}$	0.55	0.57	0.60	$\boxed{2.8}$	$\boxed{0.04}$	$\boxed{0.19}$
Cd Cadmium	$\boxed{6.9}$	2.2	1.9	2.0	$\boxed{13}$	$\boxed{0.21}$	$\boxed{0.91}$
Cr Chromium	$\boxed{35}$	22	19	20	$\boxed{96}$	$\boxed{1.5}$	$\boxed{6.7}$
Cu Copper	$\boxed{350}$	11	9.5	10	$\boxed{380}$	$\boxed{6.0}$	$\boxed{26}$
Fe Iron	$\boxed{620}$	$\boxed{37}$	$\boxed{10}$	30	$\boxed{700}$	$\boxed{11}$	$\boxed{49}$
Li Lithium	3.1	2.2	1.9	$\boxed{4.0}$	$\boxed{11}$	$\boxed{0.18}$	$\boxed{0.79}$
Mn Manganese	$\boxed{12}$	5.5	5.7	6.0	$\boxed{29}$	$\boxed{0.47}$	$\boxed{2.1}$
Ni Nickel	$\boxed{35}$	22	19	20	$\boxed{96}$	$\boxed{1.5}$	$\boxed{6.7}$
Pb Lead	$\boxed{69}$	$\boxed{39}$	19	20	$\boxed{150}$	$\boxed{2.3}$	$\boxed{10}$
Sr Strontium	14	11	$\boxed{9.5}$	$\boxed{10}$	$\boxed{44}$	$\boxed{0.07}$	$\boxed{0.3}$
Ti Titanium	310	220	190	$\boxed{200}$	$\boxed{920}$	$\boxed{15}$	$\boxed{65}$
Zn Zinc	$\boxed{450}$	$\boxed{50}$	$\boxed{19}$	$\boxed{6}$	$\boxed{520}$	$\boxed{8.3}$	$\boxed{37}$

All values except those in boxes ☐ are below the limit of detection

Table IV.14: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Gulf-Strachan Plant:
Test #2 - Borosilicate Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD
LOCATION: STRACHAN
COMPANY: GULF

2) TEST NO: 3 DATE: August 24, 1982

3) PRODUCTION: 2.22 x 10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.95 (inches Hg)
STATIC PRESSURE: -2.1 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D)15 8/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.885
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 0.50 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 4.17, O_2 14.24, CO 0.28
SO_2 0.30, N_2 80.06, Ar 0.95

7) NO. OF READINGS: 48
TIME BETWEEN READINGS: 4 min.
TEST POINTS/TRAVERSE: 8
NO. OF TRAVERSES: 3

8) CONDENSED WATER: 350.3 (grams)
WATER CAUGHT BY DRYING AGENTS: 5.2 (grams)
MOISTURE CONTENT, B_{wo}: 0.165

9) MOLECULAR WEIGHT OF GAS:
29.46 DRY BASIS (lb_m/lb mole)
27.57 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 98.46 (acf)

11) AVERAGE STACK VELOCITY: 19.67 (ft/s) AVG.TEMP: 940 (°F)
AVERAGE VOLUMETRIC FLOW RATE: 230,000 (acfm)

Table IV.15 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	940	0.03	18.34	0.48	313.12	275	195	65	65	78	78	1.00	0.00
1	4	940	0.03	18.34	0.48	315.06	275	195	65	65	78	78	1.00	101.34
1	8	940	0.05	23.19	0.76	317.38	270	265	59	132	78	80	2.50	95.96
2	12	940	0.04	21.70	0.67	319.73	275	295	55	150	78	80	2.00	103.62
2	16	940	0.04	21.17	0.64	321.90	270	315	56	162	79	81	2.00	98.05
3	20	940	0.05	23.67	0.80	324.27	270	315	56	162	79	81	3.00	95.74
3	24	940	0.04	19.81	0.56	326.18	270	295	56	172	80	84	2.00	91.97
4	28	960	0.03	18.47	0.48	327.91	270	295	59	170	80	84	1.00	90.15
4	32	950	0.02	16.80	0.40	329.54	270	290	60	165	80	84	0.75	93.17
5	36	950	0.02	15.03	0.32	331.23	270	290	60	165	80	84	0.50	107.55
5	40	950	0.02	15.03	0.32	332.90	270	290	60	165	80	84	0.50	106.79
6	44	940	0.02	14.20	0.29	334.28	270	280	61	160	80	82	0.50	92.78
6	48	940	0.02	15.70	0.35	335.86	270	280	61	165	80	82	0.50	95.62
7	52	940	0.02	15.70	0.35	337.48	270	280	61	165	80	82	0.50	98.57
7	56	935	0.02	13.78	0.27	338.80	270	282	61	167	79	81	0.50	90.81
8	60	935	0.02	13.78	0.27	340.21	270	282	61	167	79	81	0.50	97.72
8	64	935	0.02	12.94	0.24	341.70	270	282	62	157	80	81	0.50	109.01

Table IV.16 : Field Sampling Data for Test #3, Gulf - Strachan, Traverse #2, August 24, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	940	0.05	22.71	0.73	341.70	275	240	68	70	72	72	2.20	0.00
1	4	940	0.05	22.71	0.73	343.92	275	240	64	120	72	74	2.20	94.60
1	8	950	0.05	23.76	0.79	346.52	270	230	57	131	75	76	2.20	106.43
2	12	940	0.05	24.83	0.87	349.28	275	240	58	138	74	79	2.80	107.14
2	16	935	0.05	22.42	0.71	351.74	275	255	58	146	75	79	2.10	104.96
3	20	940	0.04	21.95	0.68	354.15	275	265	59	149	76	80	2.20	105.47
3	24	945	0.04	21.21	0.63	356.54	270	265	59	158	77	80	2.10	108.11
4	28	945	0.04	21.21	0.63	358.73	285	270	60	165	78	80	2.10	99.44
4	32	940	0.04	19.81	0.56	360.88	295	275	60	165	79	81	2.80	103.60
5	36	940	0.04	21.17	0.63	363.24	290	280	60	165	80	81	2.00	106.60
5	40	935	0.04	21.14	0.63	365.62	290	285	60	175	79	81	2.00	107.13
6	44	945	0.04	21.21	0.63	367.91	290	300	60	180	80	82	2.10	103.41
6	48	930	0.04	21.10	0.63	370.06	290	305	60	180	80	81	2.10	96.32
7	52	930	0.03	18.27	0.47	372.12	285	315	60	171	80	82	1.90	107.13
7	56	930	0.03	18.27	0.47	373.98	285	315	60	171	80	82	1.90	95.98
8	60	920	0.02	16.62	0.39	375.59	290	325	60	170	80	81	1.50	91.57
8	64	920	0.02	15.59	0.36	377.35	290	325	60	170	80	81	1.50	105.64

Table IV.17 : Field Sampling Data for Test #3, Gulf - Strachan, Traverse #3, August 24, 1982

Sample Analyses Test No 3 Date August 24, 1982 Strachan

Sample From	P&N 6N HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	435	620	216		$E_R = 5.9 \times 10^4$		kg/d (total)
Total Particulate (mg)	63	41000	-	14	$E_R = 1.1 \times 10^2$		kg/d (front end)
Al Aluminum	130	$\boxed{120}$	110	$\boxed{2600}$	$\boxed{3000}$	$\boxed{39}$	$\boxed{180}$
As Arsenic	0.87	$\boxed{1.2}$	0.65	$\boxed{0.90}$	$\boxed{3.7}$	$\boxed{0.05}$	$\boxed{0.22}$
Cd Cadmium	$\boxed{4.4}$	2.5	2.2	2.0	$\boxed{7.7}$	$\boxed{0.10}$	$\boxed{0.46}$
Cr. Chromium	$\boxed{44}$	25	22	20	$\boxed{110}$	$\boxed{1.5}$	$\boxed{6.5}$
Fe Iron	$\boxed{380}$	$\boxed{37}$	$\boxed{22}$	$\boxed{40}$	$\boxed{480}$	$\boxed{6.3}$	$\boxed{28}$
Li Lithium	3.0	2.5	2.2	$\boxed{2.0}$	$\boxed{9.7}$	$\boxed{0.13}$	$\boxed{0.56}$
Mo Molybdenum	$\boxed{87}$	25	22	30	$\boxed{160}$	$\boxed{2.2}$	$\boxed{9.7}$
Ni Nickel	$\boxed{44}$	25	22	20	$\boxed{110}$	$\boxed{1.5}$	$\boxed{6.5}$
Pb Lead	$\boxed{87}$	$\boxed{37}$	22	20	$\boxed{170}$	$\boxed{2.2}$	$\boxed{9.6}$
Te Tellurium	87	62	65	60	270	3.6	16
Ti Titanium	300	$\boxed{250}$	220	100	$\boxed{370}$	$\boxed{11}$	$\boxed{52}$
Tl Thallium	44	$\boxed{37}$	43	40	$\boxed{164}$	$\boxed{2.2}$	$\boxed{9.7}$
Zn Zinc	$\boxed{250}$	$\boxed{62}$	$\boxed{30}$	$\boxed{5.6}$	$\boxed{350}$	$\boxed{4.6}$	$\boxed{21}$

All values except those in boxes ☐ are under the limit of detection

Table IV.18: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Gulf-Strachan Plant:
Test #3 - Borosilicate Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD
LOCATION: RAM RIVER
COMPANY: CANTERRA

2) TEST NO: Prelim DATE: August 25/82

3) PRODUCTION: 5.98 x 10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.48 (inches Hg)
STATIC PRESSURE: -1.6 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D) 20 1/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.896
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 0.25 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 6.99, O_2 9.42, CO 0.04
SO_2 0.22, N_2 81.99, Ar 0.98

7) NO. OF READINGS: 48
TIME BETWEEN READINGS: 6 min.
TEST POINTS/TRAVERSE: 12
NO. OF TRAVERSES: 2

8) CONDENSED WATER: 224.2 (grams)
WATER CAUGHT BY DRYING AGENTS: 10.5 (grams)
MOISTURE CONTENT, B_{wo}: 0.242

9) MOLECULAR WEIGHT OF GAS:
29.69 DRY BASIS (lb_m/lb mole)
26.86 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 40.70 (acf)

11) AVERAGE STACK VELOCITY: 54.59 (ft/s) AVG. TEMP: 1079 (°F)
AVERAGE VOLUMETRIC FLOW RATE: 1000000 (acfm)

Table IV.19 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1090	0.27	59.93	1.20	413.70	240	230	52	52	54	58	11.00	0.00
1	6	1090	0.27	59.93	1.20	415.37	240	230	52	52	54	58	11.00	90.67
2	12	1090	0.26	58.81	1.15	417.08	240	270	280	135	59	61	12.00	94.06
3	18	1090	0.26	58.81	1.15	419.05	240	270	280	135	59	61	12.00	108.30
4	24	1080	0.26	58.62	1.15	420.94	240	270	280	135	59	61	12.00	103.23
5	30	1090	0.25	57.67	1.15	422.82	240	330	59	200	62	70	12.00	104.62
6	36	1090	0.26	58.81	1.15	424.64	240	330	59	200	62	70	12.00	98.67
7	42	1085	0.26	58.71	1.15	426.31	240	330	59	200	62	70	12.00	90.36
8	48	1075	0.26	58.52	1.15	428.06	240	320	59	210	69	74	12.00	94.11
9	54	1070	0.26	58.43	1.15	429.77	240	320	59	210	69	74	12.00	91.35
10	60	1065	0.21	62.43	0.93	431.48	240	320	59	210	69	74	12.00	101.14
11	66	1070	0.12	39.69	0.53	432.81	240	320	59	210	69	74	12.00	104.60
12	72	1040	0.05	25.37	0.22	433.62	240	320	55	180	70	75	3.00	97.28

Table IV.20 Field Sampling Data for Preliminary Survey, Canterra - Ram River, Traverse #1, August 25, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1090	0.27	59.93	1.20	433.62	240	230	52	52	54	58	11.00	0.00
1	6	1090	0.27	59.93	1.20	435.51	240	230	52	52	54	58	11.00	102.39
2	12	1090	0.27	59.93	1.15	437.33	240	270	280	135	59	61	12.00	98.53
3	18	1090	0.27	59.93	1.15	439.37	240	270	280	135	59	61	12.00	109.68
4	24	1080	0.27	59.74	1.15	441.07	240	270	280	135	59	61	12.00	91.31
5	30	1090	0.25	57.67	1.15	442.88	240	330	59	200	62	70	12.00	100.66
6	36	1090	0.27	59.93	1.15	444.80	240	330	59	200	62	70	12.00	102.20
7	42	1085	0.27	59.83	1.15	446.82	240	330	59	200	62	70	12.00	107.22
8	48	1075	0.27	59.64	1.15	448.79	240	320	59	210	69	74	12.00	103.43
9	54	1070	0.27	59.54	1.15	450.61	240	320	59	210	69	74	12.00	95.67
10	60	1065	0.21	52.43	0.93	452.35	240	320	59	210	69	74	12.00	103.11
11	66	1070	0.12	39.69	0.53	453.59	240	320	59	210	69	74	12.00	97.53
12	72	1040	0.05	25.37	0.22	454.40	240	320	55	180	70	75	3.00	97.23

Table IV. 21 Field Sampling Data for Preliminary Survey, Canterra - Ram River, Traverse #2, August 25, 1982.

Sample Analyses   Test No Prelim   Date   August 25, 1982   Ram River

Sample From	P&M 6N HNO_3	IMP. 1	IMP. 2,3	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	490	470	475	190		$E_R = 3.2 \times 10^4$		kg/d (total)
Total Particulate (mg)	25	-	4400	-	12	$E_R = 2.6 \times 10^2$		kg/d (front end)
Fe Iron	$\boxed{290}$	190	190	76	40	$\boxed{790}$	$\boxed{13}$	$\boxed{230}$
Zn Zinc	$\boxed{250}$	$\boxed{38}$	$\boxed{48}$	$\boxed{25}$	$\boxed{880}$	$\boxed{1200}$	$\boxed{20}$	$\boxed{370}$

All values except those in boxes ☐ are below the limit of detection

Table IV.22: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Canterra - Ram River Plant: Preliminary Survey - Borosilicate Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: RAM RIVER

COMPANY: CANTERRA

2) TEST NO: Test #1 DATE: August 26/82

3) PRODUCTION: 5.90×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.48 (inches Hg)

STATIC PRESSURE: -1.6 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 20 1/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.896

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.25 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 8.33, O_2 8.69, CO 0.15

SO_2 0.20, N_2 81.66, Ar 0.97

7) NO. OF READINGS: 96

TIME BETWEEN READINGS: 3 min.

TEST POINTS/TRAVERSE: 12

NO. OF TRAVERSES: 4

8) CONDENSED WATER: 504.8 (grams)

WATER CAUGHT BY DRYING AGENTS: 6.3 (grams)

MOISTURE CONTENT, B_{wo}: 0.249

9) MOLECULAR WEIGHT OF GAS:

29.87 DRY BASIS (lb_m/lb mole)

26.92 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 85.887 (acf)

11) AVERAGE STACK VELOCITY: 57.45 (ft/s) AVG. TEMP: 1085 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 1100060 (acfm)

Table IV.23 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	1090	0.28	60.96	0.24	539.36	270	240	42	42	55	59	1.00	0.00
1	3	1090	0.28	60.96	0.24	540.21	270	240	42	42	55	59	1.00	91.34
1	6	1090	0.28	60.96	0.24	541.13	270	240	42	42	55	59	1.00	98.12
2	9	1090	0.29	62.04	0.25	542.14	270	240	48	105	57	58	1.00	106.60
2	12	1090	0.29	62.04	0.25	543.05	270	240	48	105	57	58	1.00	96.45
3	15	1090	0.29	62.04	0.25	544.00	270	255	40	130	56	58	1.00	99.25
3	18	1090	0.29	62.04	0.25	545.02	270	255	40	130	56	58	1.00	107.35
4	21	1090	0.31	64.14	0.27	545.91	260	285	40	142	58	59	1.00	90.73
4	24	1090	0.31	64.14	0.27	546.87	260	285	40	142	58	59	1.00	98.22
5	27	1090	0.31	64.14	0.27	547.79	260	315	42	155	57	60	1.00	92.72
5	30	1090	0.31	64.14	0.27	548.69	260	315	42	155	57	60	1.00	92.29
6	33	1090	0.30	63.10	0.26	549.66	260	308	41	165	59	60	1.00	99.20
6	36	1090	0.30	63.10	0.26	550.67	260	308	41	165	59	60	1.00	104.61
7	39	1090	0.30	63.10	0.26	551.59	260	308	41	165	59	60	1.00	94.77
7	42	1090	0.30	63.10	0.26	552.63	260	308	41	165	59	60	1.00	107.06
8	45	1085	0.29	61.94	0.25	553.67	250	305	42	167	59	62	1.20	109.37
8	48	1085	0.29	61.94	0.25	554.56	250	305	42	167	59	62	1.20	92.60
9	51	1080	0.28	60.76	0.24	555,42	250	305	42	162	59	62	1.20	91.34
9	54	1080	0.28	60.76	0.24	556.31	250	305	42	162	59	62	1.20	94.40
10	57	1080	0.28	60.76	0.24	557.29	256	300	42	166	60	62	1.00	104.43
10	60	1080	0.28	60.76	0.24	558.21	256	300	42	166	60	62	1.00	96.87
11	63	1090	0.19	50.22	0.16	558.99	260	300	41	162	60	62	0.50	101.36
11	66	1090	0.19	50.22	0.16	559.74	260	300	41	162	60	62	0.50	96.22
12	69	1050	0.06	27.85	0.05	560.20	265	295	42	145	60	61	0.50	105.09
12	72	1050	0.06	27.85	0.05	560.66	265	295	42	145	60	61	0.50	104.48

Table IV.24 : Field Sampling Data for Test #1, Canterra - Ram River, Traverse #1, August 26, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1075	0.30	62.79	0.26	560.66	235	230	46	42	52	52	1.00	0.00
1	3	1075	0.30	62.79	0.26	561.63	235	230	46	42	52	52	1.00	101.11
1	6	1080	0.30	62.90	0.26	562.65	235	230	42	95	52	52	1.00	106.26
2	9	1080	0.30	62.90	0.26	563.68	240	245	42	128	52	52	1.10	107.64
2	12	1090	0.31	64.14	0.27	564.74	240	275	42	138	52	53	1.10	109.37
3	15	1095	0.31	64.25	0.27	565.79	240	295	42	145	52	53	1.10	107.43
3	18	1095	0.31	64.25	0.27	566.76	240	295	42	145	52	53	1.10	100.11
4	21	1085	0.31	64.04	0.27	567.68	245	312	42	157	55	56	1.20	93.78
4	24	1085	0.31	64.04	0.27	568.67	245	312	42	157	55	56	1.20	101.50
5	27	1085	0.31	64.04	0.27	569.70	245	312	42	157	55	56	1.20	105.14
5	30	1085	0.31	64.04	0.27	570.66	240	300	42	157	56	58	1.30	97.16
6	33	1085	0.31	64.04	0.27	571.61	240	300	42	157	56	58	1.30	96.69
6	36	1090	0.30	63.10	0.26	572.63	240	300	42	158	58	60	1.20	105.60
7	39	1090	0.30	63.10	0.26	573.63	240	300	42	158	58	60	1.20	103.40
7	42	1085	0.29	61.94	0.25	574.68	235	300	43	162	58	61	1.20	109.96
8	45	1085	0.29	61.94	0.25	575.72	235	300	43	162	58	61	1.20	109.06
8	48	1090	0.28	60.96	0.24	576.71	235	300	44	165	61	62	1.20	104.67
9	51	1085	0.27	59.76	0.24	577.69	235	300	42	168	62	63	1.20	106.29
9	54	1080	0.27	59.67	0.24	578.58	235	300	44	168	62	64	1.20	95.69
10	57	1080	0.27	59.67	0.24	579.49	235	300	44	168	62	64	1.20	97.43
10	60	1075	0.24	56.16	0.21	580.39	235	300	44	168	62	64	1.00	103.22
11	63	1075	0.24	56.16	0.21	581.29	235	300	44	168	62	64	1.00	102.30
11	66	1070	0.16	45.78	0.14	582.04	240	305	45	145	62	64	1.00	104.79
12	69	1070	0.16	45.78	0.14	582.82	240	305	45	145	62	64	1.00	108.06
12	72	1055	0.05	25.47	0.04	583.24	240	310	48	110	62	64	1.00	105.07

Table IV.25 : Field Sampling Data for Test #1, Canterra - Ram River, Traverse #2, August 26, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1095	0.30	63.20	0.26	583.24	245	310	48	82	62	62	1.30	0.00
1	3	1095	0.30	63.20	0.26	584.19	245	310	48	82	62	62	1.30	97.91
1	6	1085	0.29	61.94	0.25	585.17	240	305	48	160	62	64	1.30	101.76
2	9	1085	0.29	61.94	0.25	586.23	240	305	48	160	62	64	1.30	109.48
2	12	1090	0.30	63.10	0.26	587.21	240	300	47	160	62	66	2.20	100.94
3	15	1090	0.29	62.04	0.25	588.18	240	300	48	160	62	66	2.20	100.31
3	18	1095	0.29	62.14	0.25	589.08	235	305	48	165	65	68	2.20	93.26
4	21	1090	0.29	62.04	0.25	590.01	240	300	48	168	64	68	2.20	96.71
4	24	1090	0.30	63.10	0.26	591.00	240	300	48	165	65	68	2.20	100.79
5	27	1090	0.30	63.10	0.26	591.93	240	300	48	165	65	68	2.20	94.23
5	30	1090	0.28	60.96	0.24	592.86	240	300	48	168	65	68	1.20	98.30
6	33	1090	0.30	63.10	0.26	593.86	240	300	48	168	65	68	1.20	101.71
6	36	1090	0.30	63.10	0.26	594.90	235	300	48	165	65	68	1.20	105.51
7	39	1090	0.30	63.10	0.26	595.85	235	300	48	165	65	68	1.20	97.53
7	42	1085	0.30	63.00	0.26	596.80	240	305	48	165	66	68	1.10	95.62
8	45	1085	0.30	63.00	0.26	597.74	240	305	48	165	66	68	1.10	95.72
8	48	1090	0.30	63.10	0.26	598.66	240	305	46	162	65	68	1.10	93.83
9	51	1080	0.22	53.86	0.19	599.52	240	310	45	150	65	68	1.00	101.27
9	54	1080	0.22	53.86	0.19	600.39	240	310	45	150	65	68	1.00	103.27
10	57	1080	0.13	41.40	0.11	601.09	240	310	45	138	67	69	1.00	107.98
10	60	1080	0.13	41.40	0.11	601.73	240	310	45	138	67	69	1.00	98.38
11	63	1060	0.07	30.18	0.06	602.21	235	310	47	112	65	67	1.00	98.53
11	66	1060	0.07	30.18	0.06	602.71	235	310	47	112	65	67	1.00	105.46
12	69	1070	0.07	30.28	0.06	603.22	240	310	48	100	65	67	1.00	106.01
12	69	1070	0.07	30.28	0.06	603.73	240	310	48	100	65	67	1.00	106.93

Table IV.26 : Field Sampling Data for Test #1, Canterra - Ram River, Traverse #3, August 26, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1065	0.06	27.99	0.05	603.73	235	310	48	110	65	67	1.00	0.00
12	3	1065	0.06	27.99	0.05	604.20	235	310	48	110	65	67	1.00	107.32
12	6	1080	0.17	47.35	0.15	604.94	235	310	48	120	55	57	1.00	101.47
11	9	1080	0.22	53.86	0.19	605.81	235	310	46	135	65	67	1.00	102.67
11	12	1080	0.22	53.86	0.19	606.68	235	310	46	135	65	67	1.00	102.85
10	15	1080	0.26	58.55	0.23	607.51	235	310	45	141	55	57	1.00	92.89
10	18	1080	0.26	58.55	0.23	608.34	235	310	45	141	55	57	1.00	91.75
9	21	1090	0.26	58.74	0.23	609.20	235	310	46	159	65	68	1.00	94.41
9	24	1090	0.26	58.74	0.23	610.12	235	310	46	159	65	68	1.00	100.54
8	27	1085	0.26	58.65	0.23	610.98	235	300	45	160	65	68	1.00	93.56
8	30	1085	0.26	58.65	0.23	611.86	235	300	45	160	65	68	1.00	96.41
7	33	1090	0.28	60.96	0.24	612.78	235	295	46	160	65	69	1.10	96.41
7	36	1090	0.28	60.96	0.24	613.64	235	295	46	160	65	69	1.10	90.63
6	39	1090	0.28	60.96	0.24	614.55	235	290	46	155	65	69	1.10	96.05
6	42	1090	0.28	60.96	0.24	615.51	235	290	46	155	65	69	1.10	100.60
5	45	1105	0.28	61.25	0.24	616.45	235	289	45	152	66	70	1.20	99.17
5	48	1105	0.28	61.25	0.24	617.49	235	289	45	152	66	70	1.20	109.52
4	51	1095	0.28	61.06	0.24	618.48	235	285	46	155	66	70	1.10	104.65
4	54	1095	0.28	61.06	0.24	619.45	235	285	46	155	66	70	1.10	102.26
3	57	1100	0.30	63.30	0.26	620.35	235	280	46	146	65	69	1.20	91.58
3	60	1100	0.30	63.30	0.26	621.42	235	280	46	146	65	69	1.20	108.98
2	63	1095	0.28	61.06	0.24	622.46	235	280	46	152	66	70	1.10	109.66
2	66	1095	0.28	61.06	0.24	623.38	235	280	46	152	66	70	1.10	97.13
1	69	1095	0.28	61.06	0.24	624.29	235	280	46	152	66	70	1.10	95.72
1	72	1095	0.28	61.06	0.24	625.25	235	280	46	152	66	70	1.10	100.16

Table IV.27 : Field Sampling Data for Test #1, Canterra - Ram River, Traverse #4, August 26, 1982.

Sample Analyses Test No 1 Date August 26, 1982 Ram River

Sample From	P&M 6M HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/scf	Elemental Emission Rate g/hr
Volume (ml)	450	950	260	-	$E_R = 2.5 \times 10^5$		kg/d (total)
Total Particulate (mg)	17	28000	-	37	$E_R = 4.8 \times 10^2$		kg/d (front end)
Al Aluminum	$\boxed{140}$	$\boxed{95}$	100	$\boxed{5000}$	$\boxed{5300}$	$\boxed{100}$	$\boxed{2000}$
As Arsenic	0.45	0.57	0.52	$\boxed{1.6}$	$\boxed{3.1}$	$\boxed{0.04}$	$\boxed{1.1}$
Cd Cadmium	$\boxed{4.5}$	1.9	2.1	2.0	$\boxed{11}$	$\boxed{0.20}$	$\boxed{3.8}$
Fe Iron	$\boxed{63}$	$\boxed{56}$	$\boxed{42}$	$\boxed{130}$	$\boxed{290}$	$\boxed{5.5}$	$\boxed{110}$
Li Lithium	2.7	1.9	2.1	$\boxed{2.0}$	$\boxed{8.7}$	$\boxed{0.17}$	$\boxed{3.2}$
Mo Molybdenum	27	19	21	$\boxed{20}$	$\boxed{87}$	$\boxed{1.6}$	$\boxed{32}$
Pb Lead	27	$\boxed{38}$	21	20	$\boxed{110}$	$\boxed{2.0}$	$\boxed{39}$
Sn Tin	140	$\boxed{230}$	100	60	$\boxed{530}$	$\boxed{10}$	$\boxed{190}$
Sr Strontium	$\boxed{27}$	$\boxed{9.5}$	$\boxed{10}$	$\boxed{20}$	$\boxed{67}$	$\boxed{1.3}$	$\boxed{24}$
Ti Titanium	270	190	210	$\boxed{200}$	$\boxed{870}$	$\boxed{16}$	$\boxed{320}$
Zn Zinc	$\boxed{39}$	$\boxed{72}$	$\boxed{31}$	$\boxed{16}$	$\boxed{160}$	$\boxed{3.0}$	$\boxed{58}$

All values except those in boxes ☐ are below the limit of detection

Table IV.28: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Canterra - Ram River Plant:
Test #1 - Borosilicate Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: RAM RIVER

COMPANY: CANTERRA

2) TEST NO: #2 DATE: August 27/82

3) PRODUCTION: 5.53×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.48 (inches Hg)

STATIC PRESSURE: -1.2 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 20 1/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.896

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.25 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 10.12, O_2 5.28, CO 0.30

SO_2 0.17, N_2 83.14, Ar 0.99

7) NO. OF READINGS: 96

TIME BETWEEN READINGS: 3 min.

TEST POINTS/TRAVERSE: 12

NO. OF TRAVERSES: 4

8) CONDENSED WATER: 80.4 (grams)

WATER CAUGHT BY DRYING AGENTS: 15.9 (grams)

MOISTURE CONTENT, B_{wo}: 0.048

9) MOLECULAR WEIGHT OF GAS:

30.01 DRY BASIS (lb_m/lb mole)

29.43 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 105.64 (acf)

11) AVERAGE STACK VELOCITY: 54.43 (ft/s) AVG. TEMP.: 1083 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 1000000 (acfm)

Table IV.29 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F) PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN	PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
0	0	1090	0.28	58.27	0.25	643.30	265	215	65	60	65	65	0.50	0.00
1	3	1090	0.28	58.27	0.25	644.36	265	215	65	60	65	65	1.00	92.03
1	6	1090	0.28	58.27	0.25	645.63	265	215	65	60	65	65	1.00	102.19
2	9	1085	0.28	58.17	0.25	646.74	270	290	59	128	66	68	0.50	104.92
2	12	1085	0.28	58.17	0.25	648.01	270	290	59	128	66	68	0.50	109.70
3	15	1085	0.28	58.17	0.25	649.09	270	290	59	128	66	68	0.50	93.90
3	18	1085	0.28	58.17	0.25	650.20	270	290	59	128	66	68	0.50	96.01
4	21	1085	0.30	60.21	0.27	651.30	265	380	60	158	72	72	0.50	91.10
4	24	1085	0.30	60.21	0.27	652.53	265	380	60	158	72	72	0.50	102.34
5	27	1090	0.28	58.27	0.25	653.63	270	370	61	159	73	75	0.50	94.09
5	30	1090	0.28	58.27	0.25	654.84	270	370	61	159	73	75	0.50	103.44
6	33	1085	0.28	58.17	0.25	655.94	270	350	61	155	75	78	0.25	93.82
6	36	1085	0.28	58.17	0.25	657.02	270	350	61	155	75	78	0.25	91.92
7	39	1095	0.28	58.36	0.25	658.28	265	390	62	151	78	80	0.25	107.17
7	42	1095	0.28	58.36	0.25	659.40	265	390	62	151	78	80	0.25	95.59
8	45	1085	0.26	56.06	0.23	660.65	265	300	62	145	79	81	0.25	109.06
8	48	1085	0.26	56.06	0.23	661.72	265	300	62	145	79	81	0.25	93.93
9	51	1090	0.24	53.94	0.21	662.83	270	310	62	150	80	82	0.50	102.00
9	54	1090	0.24	53.94	0.21	664.00	270	310	62	150	80	82	0.50	106.62
10	57	1085	0.22	51.56	0.19	665.07	270	330	66	158	81	82	0.50	101.64
10	60	1085	0.22	51.56	0.19	666.02	270	330	66	158	81	82	0.50	90.30
11	63	1080	0.12	38.02	0.11	666.86	265	390	70	152	83	85	0.50	107.02
11	66	1080	0.12	38.02	0.11	667.71	265	390	70	152	83	85	0.50	109.33
12	69	950	0.03	18.19	0.03	668.09	265	310	72	148	83	85	0.50	92.60
12	72	950	0.03	18.19	0.03	668.46	265	310	72	148	83	85	0.50	91.71

Table IV.30 : Field Sampling Data for Test #2, Canterra - Ram River, Traverse #1, August 27, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	930	0.02	14.75	0.02	668.46	270	275	75	92	81	82	0.50	0.00
12	3	930	0.02	14.75	0.02	668.79	270	275	75	92	81	82	0.50	96.62
12	6	930	0.02	14.75	0.02	669.10	270	275	75	92	81	82	0.50	94.35
11	9	1060	0.12	37.77	0.11	669.86	265	320	72	133	82	83	0.50	96.47
11	12	1060	0.12	37.77	0.11	670.71	265	320	72	133	82	83	0.50	109.07
10	15	1080	0.22	51.48	0.19	671.83	265	340	72	149	83	84	0.50	106.16
10	18	1080	0.22	51.48	0.19	672.84	265	340	72	149	83	84	0.50	95.19
9	21	1080	0.22	51.48	0.19	673.85	265	355	73	161	83	84	0.50	95.65
9	24	1080	0.22	51.48	0.19	674.88	265	355	73	161	83	84	0.50	97.26
8	27	1090	0.26	56.15	0.24	676.05	265	366	72	170	82	83	0.50	102.71
8	30	1090	0.26	56.15	0.24	677.20	265	366	72	170	82	83	0.50	100.75
7	33	1085	0.28	58.17	0.25	678.39	270	380	74	178	82	84	0.50	100.04
7	36	1085	0.28	58.17	0.25	679.50	270	380	74	178	82	84	0.50	93.41
6	39	1085	0.28	58.17	0.25	680.70	270	360	73	175	84	88	0.50	100.13
6	42	1085	0.28	58.17	0.25	681.90	270	360	73	175	84	88	0.50	99.96
5	45	1090	0.28	58.27	0.25	683.07	270	335	72	165	85	87	0.50	98.63
5	48	1090	0.28	58.27	0.25	684.17	270	335	72	165	85	87	0.50	92.03
4	51	1085	0.28	58.17	0.25	685.42	265	328	72	165	85	88	0.50	104.46
4	54	1085	0.28	58.17	0.25	686.60	265	328	72	165	85	88	0.50	98.57
3	57	1090	0.28	58.27	0.25	687.69	265	321	70	160	84	88	0.50	91.17
3	60	1090	0.28	58.27	0.25	688.88	265	321	70	160	84	88	0.50	99.84
2	63	1085	0.28	58.17	0.24	690.06	270	320	68	155	84	88	0.50	98.45
2	66	1085	0.28	58.17	0.24	691.16	270	320	68	155	84	88	0.50	92.20
1	69	1095	0.28	58.36	0.24	692.44	270	320	68	159	85	89	0.50	107.07
1	72	1095	0.28	58.36	0.24	693.54	270	320	68	159	85	89	0.50	92.60

Table IV.31 : Field Sampling Data for Test #2, Canterra - Ram River, Traverse #2, August 27, 1982.

SAMPLE POINT	TIME	STACK TEMP	DELTA P	VEL	DELTA H	GAS METER VOLUME	TEMPERATURES (DEG.F)						PUMP VAC	ISOKINETIC VARIATION
									IMPINGERS		GAS METER			
(NO)	(MIN)	DEG.F	(IN H2O)	(FT/S)	(IN H2O)	(CUFT)	PROBE	OVEN	OUTLET	INLET	OUT	IN	(IN HG)	(PERCENT)
0	0	1090	0.28	58.27	0.25	693.54	270	200	60	69	69	69	0.50	0.00
1	3	1090	0.28	58.27	0.25	694.61	270	200	60	69	69	69	0.50	91.86
1	6	1090	0.28	58.27	0.25	695.74	270	200	60	69	69	69	0.50	97.66
2	9	1100	0.28	58.45	0.25	696.88	270	270	55	125	69	69	0.50	99.23
2	12	1100	0.28	58.45	0.25	697.99	270	270	55	125	69	69	0.50	96.43
3	15	1090	0.28	58.27	0.25	699.21	270	305	55	132	69	70	0.50	105.48
3	18	1090	0.28	58.27	0.25	700.43	270	305	55	132	69	70	0.50	104.91
4	21	1100	0.30	60.50	0.27	701.62	275	340	55	137	70	71	0.50	100.07
4	24	1100	0.30	60.50	0.27	702.77	275	340	55	137	70	71	0.50	96.17
5	27	1090	0.28	58.27	0.25	703.89	275	360	55	146	70	71	0.25	96.36
5	30	1090	0.28	58.27	0.25	704.96	275	360	55	146	70	71	0.25	92.46
6	33	1095	0.30	60.41	0.27	706.26	275	380	54	145	71	72	0.25	107.59
6	36	1095	0.30	60.41	0.27	707.38	275	380	54	145	71	72	0.25	93.27
7	39	1105	0.28	58.55	0.25	708.43	270	340	55	144	72	73	0.25	91.32
7	42	1105	0.28	58.55	0.25	709.69	270	340	55	144	72	73	0.25	108.43
8	45	1085	0.22	51.56	0.20	710.82	270	320	55	131	73	75	0.25	108.60
8	48	1085	0.22	51.56	0.20	711.81	270	320	55	131	73	75	0.25	95.74
9	51	1060	0.22	51.14	0.20	712.82	270	320	55	113	72	75	0.50	96.95
9	54	1060	0.22	51.14	0.20	713.86	270	320	55	113	72	75	0.50	99.92
10	57	1095	0.24	54.03	0.21	715.02	270	320	56	121	74	76	0.50	106.99
10	60	1095	0.24	54.03	0.21	716.13	270	320	56	121	74	76	0.50	102.61
11	63	1105	0.24	54.20	0.21	717.13	275	320	56	121	74	77	0.50	92.79
11	66	1105	0.24	54.20	0.21	718.14	275	320	56	121	74	77	0.50	93.20
12	69	1105	0.24	54.20	0.21	719.26	275	320	56	121	74	77	0.50	104.07
12	72	1105	0.24	54.20	0.21	720.40	275	320	56	121	74	77	0.50	105.42

Table IV.32 : Field Sampling Data for Test #2, Canterra - Ram River, Traverse #3, August 27, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	1105	0.24	54.20	0.21	720.40	270	310	56	82	71	72	0.50	0.00
12	3	1105	0.24	54.20	0.21	721.42	270	310	56	82	71	72	0.50	96.02
12	6	1105	0.24	54.20	0.21	722.57	270	310	56	82	71	72	0.50	107.20
11	9	1105	0.28	58.55	0.25	723.72	270	300	54	118	73	75	0.50	99.02
11	12	1105	0.28	58.55	0.25	724.99	270	300	54	118	73	75	0.50	109.28
10	15	1095	0.28	58.36	0.25	726.21	270	290	53	117	72	75	0.50	104.36
10	18	1095	0.28	58.36	0.25	727.40	270	290	53	117	72	75	0.50	102.66
9	21	1095	0.28	58.36	0.25	728.53	270	330	52	130	72	75	0.50	96.62
9	24	1095	0.28	58.36	0.25	729.64	270	330	52	130	72	75	0.50	95.82
8	27	1095	0.28	58.36	0.25	730.87	270	360	52	142	72	75	0.50	105.34
8	30	1095	0.28	58.36	0.25	732.15	270	360	52	142	72	75	0.50	109.64
7	33	1095	0.30	60.41	0.27	733.47	270	380	52	154	72	75	0.50	109.61
7	36	1095	0.30	60.41	0.27	734.56	270	380	52	154	72	75	0.50	90.94
6	39	1090	0.28	58.27	0.25	735.72	270	385	53	150	72	75	0.50	99.08
6	42	1090	0.28	58.27	0.25	736.84	270	385	53	150	72	75	0.50	95.90
5	45	1100	0.30	60.50	0.27	738.08	275	315	53	150	72	75	0.50	103.74
5	48	1100	0.30	60.50	0.27	739.28	275	315	53	150	72	75	0.50	99.28
4	51	1090	0.30	60.31	0.27	740.51	270	310	54	151	72	75	0.50	102.00
4	54	1090	0.30	60.31	0.27	741.70	270	310	54	151	72	75	0.50	98.42
3	57	1095	0.30	60.41	0.27	742.81	270	320	54	159	72	75	0.50	92.38
3	60	1095	0.30	60.41	0.27	744.12	270	320	54	159	72	75	0.50	108.48
2	63	1095	0.28	58.36	0.25	745.28	270	330	53	160	72	75	0.50	99.49
2	66	1095	0.28	58.36	0.25	746.45	270	330	53	160	72	75	0.50	100.69
1	69	1090	0.28	58.27	0.25	747.72	270	341	55	161	72	75	0.50	108.58
1	72	1090	0.28	58.27	0.25	748.94	270	341	55	161	72	75	0.50	105.26

Table IV.33 : Field Sampling Data for Test #2, Canterra - Ram River, Traverse #4, August 27, 1982.

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD
LOCATION: RAM RIVER
COMPANY: CANTERRA

2) TEST NO: #3 DATE: August 28/82

3) PRODUCTION: 5.62×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.48 (inches Hg)
STATIC PRESSURE: -1.6 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D) 20 1/12 (feet)

5) PITOT TUBE COEFFICIENT: 0.896
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 0.25 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 8.97 , O_2 8.02 , CO 0.51
SO_2 0.26 , N_2 81.27 , Ar 0.97

7) NO. OF READINGS: 96
TIME BETWEEN READINGS: 3 min.
TEST POINTS/TRAVERSE: 12
NO. OF TRAVERSES: 4

8) CONDENSED WATER: 466.4 (grams)
WATER CAUGHT BY DRYING AGENTS: 5.7 (grams)
MOISTURE CONTENT, B_{wo}: 0.231

9) MOLECULAR WEIGHT OF GAS:
29.97 DRY BASIS (lb_m/lb mole)
27.20 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 87.16 (acf)

11) AVERAGE STACK VELOCITY: 56.44 (ft/s) AVG. TEMP.: 1090 (°F)
AVERAGE VOLUMETRIC FLOW RATE: 1,100,000 (acfm)

Table IV.34 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F) PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN	PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
0	0	1105	0.30	63.07	0.25	756.25	270	235	50	49	49	50	0.50	0.00
1	3	1105	0.30	63.07	0.25	757.14	270	235	50	49	49	50	0.50	92.69
1	6	1105	0.30	63.07	0.25	758.16	270	235	50	49	49	50	0.50	106.25
2	9	1095	0.28	60.74	0.24	759.13	270	290	48	141	51	52	0.50	103.23
2	12	1095	0.28	60.74	0.24	760.10	270	290	48	141	51	52	0.50	102.92
3	15	1100	0.30	62.97	0.25	761.16	270	319	49	155	55	57	0.50	108.52
3	18	1100	0.30	62.97	0.25	762.18	270	319	49	155	55	57	0.50	104.70
4	21	1105	0.28	60.93	0.24	763.05	270	343	49	164	56	59	0.50	91.47
4	24	1105	0.28	60.93	0.24	764.05	270	343	49	164	56	59	0.50	106.44
5	27	1105	0.30	63.07	0.25	764.99	270	368	50	150	60	61	0.50	95.45
5	30	1105	0.30	63.07	0.25	765.92	270	368	50	150	60	61	0.50	94.58
6	33	1100	0.30	62.97	0.25	766.99	270	380	49	183	61	63	0.50	108.43
6	36	1100	0.30	62.97	0.25	767.98	270	380	49	183	61	63	0.50	99.24
7	39	1100	0.26	58.62	0.22	768.90	270	300	49	170	62	67	0.50	99.54
7	42	1100	0.26	58.62	0.22	769.86	270	300	49	170	62	67	0.50	104.14
8	45	1105	0.26	58.72	0.22	770.87	270	295	50	161	64	68	0.50	108.75
8	48	1105	0.26	58.72	0.22	771.75	270	295	50	161	64	68	0.50	95.23
9	51	1095	0.26	58.53	0.22	772.61	270	300	49	163	65	69	0.50	92.67
9	54	1095	0.26	58.53	0.22	773.53	270	300	49	163	65	69	0.50	98.81
10	57	1095	0.22	53.84	0.19	774.38	270	308	50	169	66	70	0.50	98.86
10	60	1095	0.22	53.84	0.19	775.27	270	308	50	169	66	70	0.50	103.76
11	63	1085	0.04	22.88	0.03	775.61	265	314	51	158	68	71	0.25	92.70
11	66	1085	0.04	22.88	0.03	775.99	265	314	51	158	68	71	0.25	102.44
12	69	1070	0.04	22.77	0.03	776.36	265	322	55	111	70	71	0.25	100.17
12	72	1070	0.04	22.77	0.03	776.73	265	322	55	111	70	71	0.25	98.92

Table IV.35 : Field Sampling Data for Test #3, Canterra - Ram River, Traverse #1, August 28, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1085	0.16	45.77	0.14	776.73	265	325	49	158	68	70	0.25	0.00
12	3	1085	0.16	45.77	0.14	777.40	265	325	49	158	68	70	0.25	92.21
12	6	1085	0.16	45.77	0.14	778.16	265	325	49	158	68	70	0.25	102.54
11	9	1095	0.26	58.53	0.22	779.14	270	329	51	159	69	71	0.50	105.29
11	12	1095	0.26	58.53	0.22	780.16	270	329	51	159	69	71	0.50	108.78
10	15	1100	0.28	60.83	0.24	781.18	270	332	51	172	69	71	0.50	104.87
10	18	1100	0.28	60.83	0.24	782.05	270	332	51	172	69	71	0.50	90.25
9	21	1095	0.28	60.74	0.24	783.00	265	334	52	173	70	72	0.50	97.54
9	24	1095	0.28	60.74	0.24	783.91	265	334	52	173	70	72	0.50	93.05
8	27	1095	0.32	64.93	0.27	784.95	265	338	52	184	70	73	0.50	100.28
8	30	1095	0.32	64.93	0.27	786.04	265	338	52	184	70	73	0.50	104.33
7	33	1100	0.30	62.97	0.25	787.08	270	340	52	189	71	74	0.50	103.39
7	36	1100	0.30	62.97	0.25	788.10	270	340	52	189	71	74	0.50	101.23
6	39	1095	0.28	60.74	0.24	789.05	270	340	52	184	72	75	0.50	96.83
6	42	1095	0.28	60.74	0.24	790.13	270	340	52	184	72	75	0.50	109.96
5	45	1095	0.28	60.74	0.24	791.18	270	344	54	181	72	75	0.50	108.16
5	48	1095	0.28	60.74	0.24	792.15	270	344	54	181	72	75	0.50	99.38
4	51	1095	0.30	62.87	0.25	793.20	270	340	53	181	74	78	0.50	102.62
4	54	1095	0.30	62.87	0.25	794.23	270	340	53	181	74	78	0.50	101.42
3	57	1095	0.30	62.87	0.25	795.29	270	340	54	172	73	78	0.50	104.88
3	60	1095	0.30	62.87	0.25	796.27	270	340	54	172	73	78	0.50	96.44
2	63	1090	0.30	62.77	0.25	797.24	265	341	55	181	73	78	0.50	94.61
2	66	1090	0.30	62.77	0.25	798.25	265	341	55	181	73	78	0.50	99.60
1	69	1095	0.28	60.74	0.24	799.29	265	342	55	170	73	78	0.50	106.12
1	72	1095	0.28	60.74	0.24	800.27	265	342	55	170	73	78	0.50	100.15

Table IV.36 : Field Sampling Data for Test #3, Canterra - Ram River, Traverse #2, August 28, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1085	0.28	60.54	0.24	800.27	265	174	51	51	58	58	0.50	0.00
1	3	1085	0.28	60.54	0.24	801.28	265	174	51	51	58	58	0.50	105.81
1	6	1085	0.28	60.54	0.24	802.17	265	174	51	51	58	58	0.50	93.54
2	9	1085	0.28	60.54	0.24	803.21	265	249	47	123	59	60	0.50	108.90
2	12	1085	0.28	60.54	0.24	804.09	265	249	47	123	59	60	0.50	91.91
3	15	1090	0.28	60.64	0.24	804.96	270	305	47	140	61	62	0.50	90.66
3	18	1090	0.28	60.64	0.24	805.88	270	305	47	140	61	62	0.50	96.55
4	21	1090	0.28	60.64	0.24	806.88	270	334	47	152	61	62	0.50	103.44
4	24	1090	0.28	60.64	0.24	807.75	270	334	47	152	61	62	0.50	91.58
5	27	1095	0.30	62.87	0.26	808.73	270	358	47	161	61	63	0.50	98.47
5	30	1095	0.30	62.87	0.26	809.78	270	358	47	161	61	63	0.50	106.63
6	33	1085	0.28	60.54	0.24	810.68	270	379	47	171	62	64	0.50	93.45
6	36	1085	0.28	60.54	0.24	811.65	270	379	47	171	62	64	0.50	101.04
7	39	1090	0.28	60.64	0.24	812.67	270	392	49	169	63	66	0.50	105.10
7	42	1090	0.28	60.64	0.24	813.64	270	392	49	169	63	66	0.50	101.25
8	45	1090	0.26	58.43	0.23	814.59	270	330	48	192	65	70	0.50	101.49
8	48	1090	0.26	58.43	0.23	815.50	270	330	48	192	65	70	0.50	97.67
9	51	1095	0.22	53.84	0.19	816.29	270	285	46	189	66	71	2.50	92.60
9	54	1095	0.22	53.84	0.19	817.12	270	285	46	189	66	71	2.50	96.55
10	57	1085	0.24	56.05	0.21	818.08	270	320	47	190	68	72	2.50	105.98
10	60	1085	0.24	56.05	0.21	819.04	270	320	47	190	68	72	2.50	106.82
11	63	1085	0.20	51.17	0.17	819.93	270	353	48	198	69	73	2.50	107.05
11	66	1085	0.20	51.17	0.17	820.76	270	353	48	198	69	73	2.50	100.93
12	69	1075	0.12	39.51	0.10	821.41	265	329	49	195	70	73	2.50	102.09
12	72	1075	0.12	39.51	0.10	822.08	265	329	49	195	70	73	2.50	103.91

Table IV.37 : Field Sampling Data for Test #3, Canterra - Ram River, Traverse #3, August 28, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	1045	0.05	25.25	0.04	822.08	260	295	53	116	70	72	2.50	0.00
12	3	1045	0.05	25.25	0.04	822.52	260	295	53	116	70	72	2.50	104.66
12	6	1045	0.05	25.25	0.04	822.91	260	295	53	116	70	72	2.50	92.92
11	9	1085	0.16	45.77	0.14	823.61	265	277	51	172	71	74	2.50	95.37
11	12	1085	0.16	45.77	0.14	824.32	265	277	51	172	71	74	2.50	95.70
10	15	1085	0.24	56.05	0.21	825.19	265	280	51	172	71	75	2.50	95.81
10	18	1085	0.24	56.05	0.21	826.04	265	280	51	172	71	75	2.50	93.52
9	21	1090	0.26	58.43	0.23	826.97	270	285	52	170	71	75	2.50	98.83
9	24	1090	0.26	58.43	0.23	827.83	270	285	52	170	71	75	2.50	91.09
8	27	1090	0.26	58.43	0.23	828.75	270	290	54	172	71	75	2.50	97.13
8	30	1090	0.26	58.43	0.23	829.72	270	290	54	172	71	75	2.50	102.85
7	33	1085	0.28	60.54	0.24	830.73	270	305	53	172	71	76	2.50	102.81
7	36	1085	0.28	60.54	0.24	831.62	270	305	53	172	71	76	2.50	91.27
6	39	1095	0.26	58.53	0.23	832.59	270	318	57	175	72	78	3.00	102.09
6	42	1095	0.26	58.53	0.23	833.45	270	318	57	175	72	78	3.00	91.21
5	45	1085	0.26	58.34	0.23	834.47	270	326	59	179	72	78	3.25	108.32
5	48	1085	0.26	58.34	0.23	835.51	270	326	59	179	72	78	3.25	109.05
4	51	1085	0.28	60.54	0.24	836.47	270	334	61	185	63	68	3.00	99.35
4	54	1085	0.28	60.54	0.24	837.38	270	334	61	185	63	68	3.00	94.55
3	57	1090	0.30	62.77	0.26	838.33	270	340	61	189	74	79	3.00	93.17
3	60	1090	0.30	62.77	0.26	839.43	270	340	61	189	74	79	3.00	107.97
2	63	1085	0.28	60.54	0.24	840.51	270	342	65	189	73	78	3.00	109.32
2	66	1085	0.28	60.54	0.24	841.53	270	342	65	189	73	78	3.00	104.24
1	69	1095	0.28	60.74	0.24	842.53	275	345	63	190	72	76	3.00	101.43
1	72	1095	0.28	60.74	0.24	843.41	275	345	63	190	72	76	3.00	90.33

Table IV.38 : Field Sampling Data for Test #3, Canterra - Ram River, Traverse #4, August 28, 1982.

Sample Analyses Test No 3 Date August 28, 1982 Ram River

Sample From	P&W 6N HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/scf	Elemental Emission Rate g/hr
Volume (ml)	600	925	215		$E_R = 2.1 \times 10^5$		kg/d (total)
Total Particulate (mg)	49	32000	32	-	$E_R = 5.3 \times 10^2$		kg/d (front end)
Al Aluminum	$\boxed{120}$	93	110	$\boxed{10000}$	$\boxed{10000}$	$\boxed{150}$	$\boxed{2800}$
Cd Cadmium	$\boxed{3.6}$	2.8	2.2	2.0	$\boxed{11}$	$\boxed{0.15}$	$\boxed{2.9}$
Cr Chromium	$\boxed{60}$	28	22	20	$\boxed{130}$	$\boxed{1.9}$	$\boxed{35}$
Cu Copper	$\boxed{24}$	9.3	11	10	$\boxed{54}$	$\boxed{0.78}$	$\boxed{15}$
Fe Iron	$\boxed{320}$	$\boxed{35}$	$\boxed{32}$	$\boxed{100}$	$\boxed{490}$	$\boxed{7.1}$	$\boxed{130}$
Li Lithium	2.4	2.8	2.2	$\boxed{4.0}$	$\boxed{11}$	$\boxed{0.16}$	$\boxed{3.1}$
Mn Manganese	$\boxed{7.2}$	5.6	6.5	6.0	$\boxed{25}$	$\boxed{0.37}$	$\boxed{6.9}$
Sr Strontium	$\boxed{12}$	$\boxed{9.3}$	11	$\boxed{20}$	$\boxed{52}$	$\boxed{0.75}$	$\boxed{14}$
Ti Titanium	240	280	220	$\boxed{200}$	$\boxed{930}$	$\boxed{13}$	$\boxed{250}$
Zn Zinc	$\boxed{37}$	$\boxed{41}$	$\boxed{20}$	$\boxed{22}$	$\boxed{120}$	$\boxed{1.7}$	$\boxed{33}$

All elements except those in boxes $\boxed{}$ are below the limit of detection

Table IV.39: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Canterra - Ram River Plant:
Test #3 - Borosilicate Glass Liner

1) CLIENT NAME: ENERGY RESOURCE CONSERVATION BOARD
LOCATION: JUMPING POUND
COMPANY: SHELL

2) TEST NO: Prelim DATE: August 30, 1982

3) PRODUCTION: 3.32 x 10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.69 (inches Hg)
STATIC PRESSURE: -1.9 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D) 5½ (feet)

5) PITOT TUBE COEFFICIENT: 0.897
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 7/32 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 14.18, O_2 9.7 , CO 0.56
SO_2 0.40, N_2 74.28 , Ar 0.88

7) NO. OF READINGS: 20
TIME BETWEEN READINGS: 3 min.
TEST POINTS/TRAVERSE: 10
NO. OF TRAVERSES: 2

8) CONDENSED WATER: 287.9 242.2 (grams)
WATER CAUGHT BY DRYING AGENTS: 4.9 (grams)
MOISTURE CONTENT, B_{wo}: 0.283

9) MOLECULAR WEIGHT OF GAS:
30.91 DRY BASIS (lb_m/lb mole)
27.26 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 34.49 (acf)

11) AVERAGE STACK VELOCITY: 154.9 (ft/s) AVE. TEMP: 1160 (°F
AVERAGE VOLUMETRIC FLOW RATE: 220,000 (acfm)

Table IV.40 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	1160	0.70	97.7	1.00	848.12	400	270	74	70	69	69	2.00	0.00
1	3	1160	0.70	97.7	1.00	849.12	400	270	74	70	69	69	2.00	93.32
2	6	1160	1.60	147.7	1.50	850.89	400	280	72	90	69	69	2.80	109.98
3	9	1160	1.90	160.9	1.50	852.64	400	280	68	136	69	70	2.80	99.97
4	12	1160	1.90	160.9	1.50	854.57	400	280	53	153	70	70	2.90	109.91
5	15	1160	1.95	163.0	1.50	856.35	400	288	53	153	70	70	4.50	99.67
6	18	1160	2.00	165.1	1.50	858.32	400	311	51	161	71	74	4.50	108.85
7	21	1160	2.00	165.1	1.50	860.06	400	311	51	161	71	74	4.50	95.95
8	24	1160	1.80	156.6	1.50	861.71	400	352	51	188	71	75	5.00	96.09
9	27	1160	1.70	152.2	1.50	863.26	400	340	51	190	72	75	5.00	92.94
10	30	1160	1.60	147.7	1.70	864.77	400	338	58	190	72	79	5.00	92.81

Table IV.41: Field Sampling Data for Preliminary Survey, Shell - Jumping Pound, Traverse #1, August 30, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	1160	1.95	163.0	1.50	864.77	400	180	50	51	56	58	5.00	0.00
1	3	1160	1.95	163.0	1.50	866.52	400	180	50	51	56	58	5.00	100.40
2	6	1160	1.95	163.0	1.50	868.39	400	260	54	140	61	61	5.00	107.07
3	9	1160	1.95	163.0	1.50	870.12	400	287	52	156	60	61	5.00	98.72
4	12	1160	1.95	163.0	1.50	872.02	400	287	52	156	60	61	5.00	108.73
5	15	1160	1.95	163.0	1.50	873.84	400	348	51	192	60	65	5.50	103.79
6	18	1160	1.95	163.0	1.50	875.68	400	312	52	196	62	69	5.00	104.20
7	21	1160	1.95	163.0	1.50	877.29	400	372	51	216	66	71	5.00	91.11
8	24	1160	1.95	163.0	1.50	879.23	400	372	51	220	67	71	5.00	108.81
9	27	1160	1.95	163.0	1.50	880.88	400	341	52	219	67	71	5.50	92.81
10	30	1160	1.95	163.0	1.50	882.61	400	312	55	218	68	71	5.50	97.65

Table IV.42: Field Sampling Data for Preliminary Survey, Shell - Jumping Pound, Traverse #2, August 30, 1982

Sample Analyses Test No Prelim Date August 30, 1982 Jumping Pound

Sample From	P&N 6N HNO$_3$	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	605	885	160		$E_R = 9.4 \times 10^4$		kg/d (total)
Total Particulate (mg)	85	37000	-	45	$E_R = 3.3 \times 10^2$		kg/d (front end)
Al Aluminum	$\boxed{240}$	$\boxed{89}$	160	$\boxed{100}$	$\boxed{590}$	$\boxed{17}$	$\boxed{63}$
As Arsenic	$\boxed{4.8}$	$\boxed{2.7}$	1.6	5.0	$\boxed{14}$	$\boxed{0.40}$	$\boxed{1.5}$
Cd Cadmium	$\boxed{350}$	2.7	3.2	2.0	$\boxed{360}$	$\boxed{10}$	$\boxed{38}$
Cr. Chromium	$\boxed{61}$	$\boxed{27}$	32	20	$\boxed{140}$	$\boxed{3.9}$	$\boxed{15}$
Cu Copper	$\boxed{48}$	$\boxed{8.9}$	16	10	$\boxed{83}$	$\boxed{2.4}$	$\boxed{8.8}$
Fe Iron	$\boxed{1900}$	$\boxed{89}$	$\boxed{32}$	$\boxed{60}$	$\boxed{2000}$	$\boxed{60}$	$\boxed{220}$
Mn Manganese	$\boxed{54}$	6.2	8.0	6.0	$\boxed{75}$	$\boxed{2.1}$	$\boxed{7.9}$
Ni Nickel	$\boxed{270}$	27	32	20	$\boxed{340}$	$\boxed{9.8}$	$\boxed{37}$
Pb Lead	$\boxed{910}$	27	32	20	$\boxed{990}$	$\boxed{28}$	$\boxed{100}$
Ti Titanium	$\boxed{240}$	$\boxed{89}$	160	60	$\boxed{550}$	$\boxed{16}$	$\boxed{58}$
Zn Zinc	$\boxed{150}$	$\boxed{62}$	4.8	$\boxed{48}$	$\boxed{260}$	$\boxed{7.4}$	$\boxed{28}$

All values except those in boxes ☐ are below the limit of dectection

Table IV.43: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell - Jumping Pound Plant: Preliminary Survey - Borosilicate Glass Liner

1) CLIENT NAME: ENERGY RESOURCE CONSERVATION BOARD

LOCATION: JUMPING POUND

COMPANY: SHELL

2) TEST NO: 1 DATE: August 31, 1982

3) PRODUCTION: 3.32×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.80 (inches Hg)

STATIC PRESSURE: -1.6 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 5½ (feet)

5) PITOT TUBE COEFFICIENT: 0.897

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 7/32 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 15.94, O_2 7.48, CO 0.66

SO_2 0.40, N_2 74.63, Ar 0.89

7) NO. OF READINGS: 40

TIME BETWEEN READINGS: 3 min.

TEST POINTS/TRAVERSE: 10

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 458.5 (grams)

WATER CAUGHT BY DRYING AGENTS: 13.9 (grams)

MOISTURE CONTENT, B_{wo}: 0.261

9) MOLECULAR WEIGHT OF GAS:

31.10 DRY BASIS (lb_m/lb mole)

27.68 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 73.33 (acf)

11) AVERAGE STACK VELOCITY: 162.3 (ft/s) AVE. TEMP: 1160 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 230000 (acfm)

Table IV.44 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1160	1.80	155.0	0.79	6.86	400	184	61	71	65	65	2.50	0.00
1	3	1160	1.80	155.0	0.79	8.51	400	184	61	71	65	65	2.50	95.03
1	6	1160	1.80	155.0	0.79	10.18	400	221	54	101	65	65	2.50	96.65
2	9	1160	2.10	167.4	0.92	11.98	400	269	53	122	66	69	3.00	95.79
2	12	1160	2.10	167.4	0.92	13.71	400	286	52	118	67	69	3.00	91.93
3	15	1160	2.60	186.3	1.14	15.69	400	312	54	122	68	69	3.50	94.58
3	18	1160	2.60	186.3	1.14	17.61	400	312	54	122	68	69	3.50	91.52
4	21	1160	2.50	182.7	1.09	19.50	400	312	54	130	68	69	3.50	92.12
4	24	1160	2.50	182.7	1.09	21.61	400	359	54	136	70	71	3.50	102.74
5	27	1160	2.50	182.7	1.09	23.84	400	340	54	139	72	75	4.00	107.35
5	30	1160	2.70	189.9	1.18	25.98	400	326	60	139	72	75	4.00	99.40
6	33	1160	2.90	196.8	1.27	28.00	400	328	61	138	72	78	4.00	90.24
6	36	1160	2.90	196.8	1.27	30.39	400	328	61	138	72	78	4.00	106.85
7	39	1160	2.30	175.2	1.00	32.56	400	330	61	138	72	78	3.50	108.96
7	42	1160	2.30	175.2	1.00	34.40	400	330	61	138	72	78	3.50	92.13
8	45	1160	1.40	136.7	0.61	35.83	400	330	61	135	72	78	2.50	92.10
8	48	1160	1.40	136.7	0.61	37.44	400	330	61	135	72	78	2.50	103.45
9	51	1160	1.90	159.3	0.83	39.12	400	330	61	132	75	79	2.00	91.80
9	54	1160	1.90	159.3	0.83	40.93	400	330	61	132	75	79	2.00	99.78
10	57	1160	1.30	131.7	0.57	42.32	400	325	61	128	75	79	2.00	92.49
10	60	1160	1.30	131.7	0.57	43.78	400	322	61	127	75	79	2.00	96.88

Table IV.45 : Field Sampling Data for Test #1, Shell - Jumping Pound, Traverse #1, August 31, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1160	2.00	163.4	0.87	43.78	400	205	62	63	69	72	3.00	0.00
1	3	1160	2.00	163.4	0.87	45.79	400	205	62	63	69	72	3.00	108.90
1	6	1160	2.00	163.4	0.87	47.67	400	271	55	118	72	72	3.00	101.47
2	9	1160	2.10	167.4	0.92	49.73	400	300	55	118	72	72	3.00	108.73
2	12	1160	2.10	167.4	0.92	51.61	400	310	55	118	72	72	3.00	99.13
3	15	1160	2.50	182.7	1.10	53.60	400	358	58	137	72	74	3.00	96.19
3	18	1160	2.50	182.7	1.10	55.77	400	358	58	137	72	74	3.00	104.99
4	21	1160	2.60	186.3	1.15	57.98	400	342	59	148	75	75	4.00	104.22
4	24	1160	2.60	186.3	1.15	60.11	400	342	59	148	75	75	4.00	100.35
5	27	1160	2.60	186.3	1.15	62.32	400	290	60	142	76	76	4.00	104.15
5	30	1160	2.60	186.3	1.15	64.48	400	290	60	142	76	76	4.00	101.75
6	33	1160	2.80	193.3	1.22	66.53	400	367	62	149	73	78	4.00	93.15
6	36	1160	2.80	193.3	1.22	68.80	400	367	62	149	73	78	4.00	103.17
7	39	1160	2.40	179.0	1.05	70.86	400	365	64	150	75	79	4.00	100.66
7	42	1160	2.40	179.0	1.05	72.81	400	365	64	150	75	79	4.00	95.42
8	45	1160	2.10	167.4	0.92	74.85	400	349	65	149	74	79	4.00	106.59
8	48	1160	2.10	167.4	0.92	76.77	400	349	65	149	74	79	4.00	100.75
9	51	1160	0.40	73.1	0.06	77.65	400	336	68	142	74	79	2.50	105.19
9	54	1160	0.40	73.1	0.06	78.52	400	339	68	142	74	79	2.50	104.39
10	57	1160	0.40	73.1	0.06	79.36	400	339	69	140	76	80	2.50	99.68
10	60	1160	0.40	73.1	0.06	80.19	400	339	69	140	76	80	2.50	98.55

Table IV.46: Field Sampling Data for Test #1, Shell - Jumping Pound, Traverse #2, August 31, 1982

1) CLIENT NAME: ENERGY RESOURCE CONSERVATION BOARD

LOCATION: JUMPING POUND

COMPANY: SHELL

2) TEST NO: 2 DATE: September 1, 1982

3) PRODUCTION: 3.32×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.91 (inches Hg)

STATIC PRESSURE: -1.6 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 5½ (feet)

5) PITOT TUBE COEFFICIENT: 0.897

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 7/32 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 16.81, O_2 5.77, CO 0.69

SO_2 0.40, N_2 75.43, Ar 0.90

7) NO. OF READINGS: 40

TIME BETWEEN READINGS: 3 min.

TEST POINTS/TRAVERSE: 10

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 342.2 (grams)

WATER CAUGHT BY DRYING AGENTS: 5.2 (grams)

MOISTURE CONTENT, B_{wo}: 0.194

9) MOLECULAR WEIGHT OF GAS:

31.17 DRY BASIS (lb_m/lb mole)

28.62 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 79.05 (acf)

11) AVERAGE STACK VELOCITY: 158.9 (ft/s) AVE. TEMP: 1160 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 230000(acfm)

Table IV.47 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1160	1.60	143.4	0.68	194.55	400	62	60	60	75	77	2.00	0.00
1	3	1160	1.60	143.4	0.68	196.18	400	62	60	60	75	77	2.00	91.51
1	6	1160	1.60	143.4	0.68	197.95	400	62	60	60	75	77	2.00	99.08
2	9	1160	1.90	156.3	0.81	199.73	400	180	51	109	79	79	2.50	90.87
2	12	1160	1.90	156.3	0.81	201.56	400	180	51	109	79	79	2.50	93.48
3	15	1160	2.50	179.3	1.05	203.87	400	244	51	115	79	80	3.00	103.04
3	18	1160	2.50	179.3	1.05	206.05	400	244	51	115	79	80	3.00	96.95
4	21	1160	2.50	179.3	1.05	208.16	400	282	51	127	78	79	3.00	94.32
4	24	1160	2.50	179.3	1.05	210.26	400	282	51	127	78	79	3.00	93.35
5	27	1160	2.70	186.3	1.13	212.38	400	321	51	148	77	79	4.00	91.26
5	30	1160	2.70	186.3	1.13	214.88	400	321	51	148	77	79	4.00	107.40
6	33	1160	2.70	186.3	1.13	217.28	400	353	51	162	78	80	4.00	103.01
6	36	1160	2.70	186.3	1.13	219.41	400	353	51	162	78	80	4.00	91.45
7	39	1160	2.40	175.7	1.00	221.64	400	334	51	164	78	80	3.50	101.66
7	42	1160	2.40	175.7	1.00	223.99	400	334	51	164	78	80	3.50	106.86
8	45	1160	2.15	166.3	0.90	226.20	400	332	50	162	78	80	3.00	104.23
8	48	1160	2.15	166.3	0.90	228.19	400	332	50	162	78	80	3.00	95.65
9	51	1160	1.75	150.0	0.50	230.03	400	325	53	161	78	80	2.00	97.83
9	54	1160	1.75	150.0	0.50	232.03	400	325	53	161	78	80	2.00	106.16
10	57	1160	0.12	39.3	0.04	232.50	400	322	58	152	81	80	0.50	96.48
10	60	1160	0.12	39.3	0.04	233.01	400	322	58	152	81	80	0.50	103.44

Table IV.48: Field Sampling Data for Test #2, Shell - Jumping Pound, Traverse #1, September 1, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1160	1.90	156.3	0.82	233.01	400	205	64	68	70	71	3.00	0.00
1	3	1160	1.90	156.3	0.82	234.79	400	205	64	68	70	71	3.00	92.31
1	6	1160	1.90	156.3	0.82	236.77	400	205	64	68	70	71	3.00	102.89
2	9	1160	2.40	175.7	1.04	239.07	400	292	53	126	69	70	3.50	106.52
2	12	1160	2.40	175.7	1.04	241.08	400	292	53	126	69	70	3.50	93.09
3	15	1160	2.60	182.8	1.12	243.36	400	338	49	138	78	79	4.00	99.83
3	18	1160	2.60	182.8	1.12	245.68	400	338	49	138	78	79	4.00	101.22
4	21	1160	2.55	181.1	1.10	248.15	400	368	49	152	79	81	4.00	108.86
4	24	1160	2.55	181.1	1.10	250.46	400	368	49	152	79	81	4.00	102.14
5	27	1160	2.70	186.3	1.20	252.65	400	350	51	155	81	83	4.00	93.09
5	30	1160	2.70	186.3	1.20	254.97	400	350	51	155	81	83	4.00	99.27
6	33	1160	2.70	186.3	1.20	257.27	400	329	52	161	82	85	4.00	97.83
6	36	1160	2.70	186.3	1.20	259.47	400	329	52	161	82	85	4.00	93.59
7	39	1160	2.20	168.2	0.98	261.61	400	351	52	170	82	86	3.50	101.04
7	42	1160	2.20	168.2	0.98	263.82	400	351	52	170	82	86	3.50	103.91
8	45	1160	1.80	152.1	0.80	265.64	400	360	52	162	84	88	3.00	94.10
8	48	1160	1.80	152.1	0.80	267.75	400	360	52	162	84	88	3.00	109.44
9	51	1160	1.10	118.9	0.49	269.41	400	351	53	155	85	89	2.00	109.68
9	54	1160	1.10	118.9	0.49	270.82	400	351	53	155	85	89	2.00	93.15
10	57	1160	1.10	118.9	0.49	272.21	400	349	55	152	87	91	2.00	91.72
10	60	1160	1.10	118.9	0.49	273.60	400	349	55	152	87	91	2.00	91.80

Table IV.49: Field Sampling Data for Test #2, Shell - Jumping Pound, Traverse #2, September 1, 1982

Sample Analyses   Test No 2   Date September 1, 1982   Jumping Pound

Sample From	P&M 6M HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/scf	Elemental Emission Rate g/hr
Volume (ml)	560	830	330		$E_R = 6.3 \times 10^4$		kg/d (total)
Total Particulate (mg)	52	40000	-	8.1	$E_R = 9.5 \times 10^1$		kg/d (front end)
Al Aluminum	$\boxed{170}$	$\boxed{83}$	$\boxed{99}$	$\boxed{100}$	$\boxed{450}$	$\boxed{7.6}$	$\boxed{30}$
Cd Cadmium	$\boxed{4.5}$	2.5	2.3	2.0	$\boxed{11}$	$\boxed{0.19}$	$\boxed{0.74}$
Cu Copper	$\boxed{28}$	8.3	9.9	$\boxed{60}$	$\boxed{110}$	$\boxed{1.8}$	$\boxed{7.0}$
Fe Iron	$\boxed{500}$	$\boxed{150}$	$\boxed{33}$	$\boxed{20}$	$\boxed{610}$	$\boxed{10}$	$\boxed{40}$
Mn Manganese	$\boxed{39}$	5.8	6.6	6.0	$\boxed{58}$	$\boxed{0.96}$	$\boxed{3.8}$
Ni Nickel	$\boxed{45}$	25	23	20	$\boxed{110}$	$\boxed{1.9}$	$\boxed{7.4}$
Pb Lead	$\boxed{28}$	25	23	20	$\boxed{96}$	$\boxed{1.6}$	$\boxed{6.3}$
Sr Strontium	5.6	5.8	6.6	$\boxed{9.0}$	$\boxed{27}$	$\boxed{0.46}$	$\boxed{1.8}$
Ti Titanium	170	$\boxed{250}$	$\boxed{230}$	60	$\boxed{710}$	$\boxed{12}$	$\boxed{47}$
Tl Thallium	56	58	66	$\boxed{50}$	$\boxed{230}$	$\boxed{3.9}$	$\boxed{15}$
Zn Zinc	$\boxed{130}$	$\boxed{25}$	$\boxed{26}$	$\boxed{88}$	$\boxed{270}$	$\boxed{4.6}$	$\boxed{18}$

All values except those in boxes ☐ are below the limit of detection

Table IV.50: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell - Jumping Pound Plant: Test #2 - Borosilicate Glass Liner

1) CLIENT NAME: ENERGY RESOURCE CONSERVATION BOARD

LOCATION: JUMPING POUND

COMPANY: SHELL

2) TEST NO: 3 DATE: September 2, 1982

3) PRODUCTION: 3.32×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.91 (inches Hg)

STATIC PRESSURE: -1.6 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 5½ (feet)

5) PITOT TUBE COEFFICIENT: 0.897

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 7/32 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 17.61, O_2 5.27 , CO 0.77

SO_2 0.40 , N_2 75.06, Ar 0.89

7) NO. OF READINGS: 40

TIME BETWEEN READINGS: 3 min.

TEST POINTS/TRAVERSE: 10

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 477.6 (grams)

WATER CAUGHT BY DRYING AGENTS: 10.6 (grams)

MOISTURE CONTENT, B_{wo}: 0.201

9) MOLECULAR WEIGHT OF GAS:

31.28 DRY BASIS (lb_m/lb mole)

28.61 DRY BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 105.78 (acf)

11) AVERAGE STACK VELOCITY: 155.9 (ft/s) AVE. TEMP: 1140 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 220000(acfm)

Table IV.51 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1140	1.95	157.4	0.88	337.10	400	98	79	82	81	81	3.00	0.00
1	4	1140	1.95	157.4	0.88	339.56	400	98	79	82	81	81	3.00	92.97
1	8	1140	1.95	157.4	0.88	341.96	400	98	79	82	81	81	3.00	90.84
2	12	1140	2.05	161.4	0.92	344.56	400	270	58	135	85	87	3.20	95.05
2	16	1140	2.05	161.4	0.92	347.10	400	310	58	150	85	87	3.20	92.74
3	20	1140	2.60	181.7	1.17	350.22	400	315	59	170	85	89	4.00	100.96
3	24	1140	2.50	178.2	1.12	352.98	400	315	61	170	88	90	3.90	91.13
4	28	1140	2.70	185.2	1.21	356.09	400	315	58	170	90	92	4.00	98.06
4	32	1140	2.70	185.2	1.21	359.52	400	320	55	170	90	95	4.00	108.21
5	36	1140	2.85	190.3	1.28	363.00	400	325	61	185	91	95	4.50	106.70
5	40	1140	2.80	188.6	1.26	366.46	400	325	60	190	93	97	4.50	106.35
6	44	1140	2.50	178.2	1.12	369.45	400	330	59	189	92	97	4.00	97.74
6	48	1140	2.50	178.2	1.12	372.80	400	331	59	180	92	97	4.00	109.33
7	52	1140	2.10	163.3	0.94	375.52	400	331	65	169	93	98	3.50	96.29
7	56	1140	2.10	163.3	0.94	378.16	400	331	66	163	94	99	3.50	93.74
8	60	1140	1.10	118.2	0.49	380.12	400	331	64	141	95	99	1.50	95.82
8	64	1140	1.10	118.2	0.49	381.99	400	329	65	129	93	98	1.00	91.29
9	68	1140	1.10	118.2	0.49	384.13	400	322	65	197	93	96	1.00	105.23
9	72	1140	1.00	112.7	0.45	386.26	400	324	65	189	92	95	1.00	109.84
10	76	1140	1.00	112.7	0.45	388.04	400	325	65	192	91	93	1.00	91.89
10	80	1140	1.00	112.7	0.45	390.02	400	317	66	175	91	92	1.00	102.79

Table IV.52: Field Sampling Data for Test #3, Shell - Jumping Pound, Traverse #1
September 2, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS		GAS METER			
									OUTLET	INLET	OUT	IN		
0	0	1140	1.80	151.2	0.81	390.02	400	195	62	85	79	79	3.00	0.00
1	4	1140	1.80	151.2	0.81	392.80	400	195	62	85	79	79	3.00	109.73
1	8	1140	2.20	167.2	0.99	395.41	400	287	52	126	79	80	4.00	93.22
2	12	1140	2.20	167.2	0.99	397.98	400	314	51	139	79	81	4.00	91.68
2	16	1140	2.20	167.2	0.99	400.55	400	352	53	160	82	85	4.00	91.12
3	20	1140	2.60	181.7	1.17	403.66	400	357	53	171	82	86	4.50	101.55
3	24	1140	2.60	181.7	1.17	407.02	400	347	54	172	83	88	4.50	109.18
4	28	1140	2.70	185.2	1.21	410.20	400	331	57	178	85	89	5.00	101.08
4	32	1140	2.70	185.2	1.21	413.47	400	328	58	182	85	90	5.00	103.88
5	36	1140	2.70	185.2	1.21	416.41	400	333	59	188	85	91	5.00	93.52
5	40	1140	2.70	185.2	1.21	419.77	400	341	60	187	88	92	5.00	106.23
6	44	1140	2.30	170.9	1.03	422.56	400	343	60	189	89	92	4.00	95.63
6	48	1140	2.30	170.9	1.03	425.42	400	342	62	185	90	93	4.00	97.74
7	52	1140	2.00	159.4	0.90	428.31	400	346	62	183	90	95	4.00	105.70
7	56	1140	2.00	159.4	0.90	430.89	400	348	63	179	90	95	4.00	94.52
8	60	1140	1.60	142.6	0.72	433.24	400	343	64	181	90	94	3.00	95.80
8	64	1140	1.60	142.6	0.72	435.78	400	339	68	190	91	95	3.00	104.05
9	68	1140	0.90	106.9	0.40	437.66	400	336	69	188	91	96	1.00	102.11
9	72	1140	0.90	106.9	0.40	439.43	400	334	71	179	91	96	1.00	96.11
10	76	1140	0.80	100.8	0.36	441.13	400	339	72	162	91	95	1.00	97.73
10	80	1140	0.80	100.8	0.36	442.88	400	334	71	162	91	94	1.00	101.27

Table IV.53: Field Sampling Data for Test #3, Shell - Jumping Pound, Traverse #2, September 2, 1982

Sample Analyses Test No 3 Date September 2, 1982 Jumping Pound

Sample From	P&M 6N HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen- tration µg/scf	Elemental Emission Rate g/hr
Volume (ml)	420	930	360		$E_R = 6.9 \times 10^4$		
Total Particulate (mg)	73	57000	-	8.8	$E_R = 1.9 \times 10^2$		
Al Aluminum	130	93	110	$\boxed{200}$	$\boxed{530}$	$\boxed{6.9}$	$\boxed{27}$
Cd Cadmium	$\boxed{4.2}$	2.8	2.5	2.0	$\boxed{12}$	$\boxed{0.15}$	$\boxed{0.56}$
Cr Chromium	$\boxed{42}$	28	25	20	$\boxed{120}$	$\boxed{1.5}$	$\boxed{5.8}$
Cu Copper	$\boxed{42}$	9.3	11	10	$\boxed{72}$	$\boxed{0.95}$	$\boxed{3.7}$
Fe Iron	$\boxed{840}$	$\boxed{74}$	$\boxed{11}$	10	$\boxed{940}$	$\boxed{12}$	$\boxed{47}$
Mn Manganese	$\boxed{42}$	5.6	7.2	6.0	$\boxed{61}$	$\boxed{0.80}$	$\boxed{3.1}$
Ni Nickel	$\boxed{84}$	28	25	20	$\boxed{160}$	$\boxed{2.1}$	$\boxed{8.0}$
Sb Antimony	42	47	36	$\boxed{60}$	$\boxed{180}$	$\boxed{2.4}$	$\boxed{9.3}$
Sn Tin	130	$\boxed{280}$	110	50	$\boxed{560}$	$\boxed{7.4}$	$\boxed{28}$
Sr Strontium	8.4	5.6	7.2	$\boxed{6.0}$	$\boxed{27}$	$\boxed{0.36}$	$\boxed{1.4}$
Zn Zinc	$\boxed{410}$	$\boxed{9.3}$	$\boxed{22}$	$\boxed{22}$	$\boxed{460}$	$\boxed{6.0}$	$\boxed{23}$

All values except those in boxes ☐ are below the limit of detection

Table IV.54: Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell - Shell Jumping Pound Plant: Test #3 - Borosilicate Glass Liner

APPENDIX V

PLANT OPERATING DATA

Variable Test	Prelim 1982 8/21	1 1982 8/22	2 1982 8/23	3 1982 8/24
Total Plant Intake 10^6 m^3/day	3.2	2.7	3.7	3.0
Total Plant Sales Gas 10^6 m^3/day	2.4	1.8	2.7	2.2
Total Acid Gas 10^6 m^3/day	0.83	0.72	0.89	0.79
Flared Gas 10^3 m^3/day	0	0	0	0
Stack Volumetric Flow Rate, 68°F, dry 10^6 m^3/day	NP	NP	NP	NP
Sulphur Emissions t/day	NP	NP	NP	NP
Stack Gas Temperature 115.8m, °C	--	451	452	441
Stack Gas Temperature 45.7m, °C	503	506	505	496
Avg. Sulphur Concentration Incinerator Stack, %	0.40	0.36	0.42	0.37

NP: NOT PROVIDED

Table V.1 Plant Operating Data at Gulf Oil Canada Limited Strachan Gas Plant

Variable Test	Prelim 1982 8/25	1 1982 8/26	2 1982 8/27	3 1982 8/28
Total Plant Intake 10^6 m^3/day	10.9	9.0	8.6	8.6
Total Plant Sales Gas 10^6 m^3/day	6.2	5.9	5.6	5.6
Total Acid Gas 10^6 m^3/day	3.3	3.0	2.9	2.9
Flared Gas 10^3 m^3/day	0	0	0	0
Stack Volumetric Flow Rate, 68°F, dry 10^6 m^3/day	NP	NP	NP	NP
Sulphur Emissions t/day	NP	NP	NP	NP
Stack Gas Temperature Top, °C	570	561	562	565
Stack Gas Temperature Bottom, °C	871	NP	NP	NP
Avg. Sulphur Concentration Incinerator Stack, %	NP	NP	NP	NP

NP: Not Provided

Table V.2 Plant Operating Data at Canterra Energy Limited Ram River Gas Plant

Variable / Test	Prelim 1982 9/30	1 1982 9/31	2 1982 10/1	3 1982 10/2
Total Plant Intake 10^6 m^3/day	4.50	4.51	4.51	4.51
Total Plant Sales Gas 10^6 m^3/day	3.32	3.32	3.32	3.32
Total Acid Gas 10^6 m^3/day	0.55	0.55	0.57	0.59
Flared Gas 10^3 m^3/day	0	0	0	0
Stack Volumetric Flow Rate, 68°F, dry 10^6 m^3/day	Not provided - Average value 0.2 x 10^6 m^3/day estimate			
Sulphur Emissions t/day	Not provided - Average value 25.6 t/day estimate			
Stack Gas Temperature Top, °C	570	580	575	572
Stack Gas Temperature Bottom, °C	720	649	652	650
Avg. Sulphur Concentration Incinerator Stack, ppm	119*	116	108	111

* Data appear too low for average of 0.66% estimate

Table V.3 Plant Operating Data at Shell Canada Limited Jumping Pound Gas Plant

APPENDIX VI

PROCEDURES FOR ESTIMATING MAXIMUM POSSIBLE EMISSION RATES OF ALL ELEMENTS OF INTEREST

APPENDIX VI.

Tables VI.1 and VI.2 summarize the maximum possible emission rates of each of the elements for 2 independent source sampling tests carried out with borosilicate glass lined probes at the Gulf-Strachan Gas Plant. Maximum possible elemental emission rates determined for 3 independent source sampling tests with a borosilicate glass lined probe at the Canterra-Ram River Gas Plant are listed in Tables VI.3 to VI.5. Three independent source sampling tests with a borosilicate glass lined probe at the Shell-Jumping Pound Gas Plant generated the maximum possible elemental emission rate data provided by Tables VI.6 to VI.8. Figures VI.1 to VI.3 illustrate the maximum mean emission rates and the corresponding ranges for the elements at the 3 sour gas plants.

For elements whose presence could not be detected in any part (probe, filter, impingers, cold trap) of the sampling train because their ultimate liquid concentrations for analysis were below the instrumental limits of detection, individual test and mean maximum possible emission rates were estimated by assuming presence at the limits of detection (LOD) values. In Figures VI.1 to VI.3, such mean emission rates are represented by open circles.

Emission rates of elements whose presence was detected, in at least one of the 4 samples recovered from the sampling train parts after each test, were evaluated from measured and limit of detection concentrations. These rates are depicted by solid circles. Open circles below the solid ones provide measures of mean maximum possible emission rates corresponding to LOD values only.

In Figures VI.1 to VI.3 all mean emission rates are bracketed to indicate the upper and lower bounds of measured or LOD magnitudes for each element under consideration.

An examination of Tables VI.1 to VI.8 and Figures VI.1 to VI.3 suggests that there is a definite need to distinguish clearly between elements whose presence was "detected" and those whose presence was "established".

An element has been classified as "detected" if an ultimate analysis solution absorbance exceeded the value corresponding to the LOD concentration as well as the laboratory blank values for that species at least once. On the other hand, the presence of an element was "established" if that element was "detected" in more than one-half of the tests or at a concentration 3 times the limit of detection (LOD).

An appreciation of the difference between a "detected" and an "established" presence of an element can be realized in terms of the values in Tables VI.6 to VI.8, pertaining to the determination of strontium. The summary of pertinent data in Table VI.9 shows that the presence of strontium was "detected" twice during analysis of the 4 samples recovered from the sampling train, after each of the 3 independent tests with the borosilicate glass lined probe.

Sample Analyses Test no 2 Date August 23, 1982 Strachan

Maximum Possible

Sample From	P&M 6x	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight μg	Elemental Concentration μg/scf	Elemental Emission Rate gm/hr
Volume (ml)	345	550	190		$E_R = 3.1 \times 10^4$		kg/d (total)
Total Particulate (mg)	25	19000	-	5.1	$E_R = 5.0 \times 10^1$		kg/d (front end)
Ag Silver	6.9	5.5	5.7	6.0	24	0.38	1.7
Al Aluminum	140	110	95	$\boxed{4000}$	$\boxed{4300}$	$\boxed{69}$	$\boxed{300}$
As Arsenic	$\boxed{1.0}$	0.55	0.57	0.60	$\boxed{2.8}$	$\boxed{0.04}$	$\boxed{0.19}$
B Boron	1500	1200	1000	1000	4700	75	330
Be Beryllium	3.1	2.2	1.9	1.0	8.2	0.13	0.58
Cd Cadmium	$\boxed{6.9}$	2.2	1.9	2.0	$\boxed{13}$	$\boxed{0.21}$	$\boxed{0.91}$
Co Cobalt	31	22	19	20	92	1.5	6.5
Cr Chromium	$\boxed{35}$	22	19	20	$\boxed{96}$	$\boxed{1.5}$	$\boxed{6.7}$
Cu Copper	$\boxed{350}$	11	9.5	10	$\boxed{380}$	$\boxed{6.0}$	$\boxed{26}$
Fe Iron	$\boxed{620}$	$\boxed{37}$	$\boxed{10}$	30	$\boxed{700}$	$\boxed{11}$	$\boxed{49}$
Ga Gallium	310	220	190	200	920	15	65
Ge Germanium	310	220	190	200	920	15	65
Hg Mercury	6.9	5.5	5.7	5.0	23	0.37	1.6
In Indium	140	110	95	100	440	7.0	31
Li Lithium	3.1	2.2	1.9	$\boxed{4.0}$	$\boxed{11}$	$\boxed{0.18}$	$\boxed{0.77}$
Mn Manganese	$\boxed{12}$	5.5	5.7	6.0	$\boxed{29}$	$\boxed{0.47}$	$\boxed{2.1}$
Mo Molybdenum	31	22	19	20	92	1.5	6.5
Ni Nickel	$\boxed{35}$	22	19	20	$\boxed{96}$	$\boxed{1.5}$	$\boxed{6.7}$
Pb Lead	$\boxed{69}$	$\boxed{39}$	19	20	$\boxed{150}$	$\boxed{2.3}$	$\boxed{10}$
Sb Antimony	69	50	38	20	180	2.8	12
Sc Scandium	100	55	57	40	260	4.1	18
Se Selenium	1.4	1.1	0.95	1.0	4.4	0.07	0.31
Sn Tin	140	110	95	60	400	6.4	28
Sr Strontium	14	11	$\boxed{9.5}$	$\boxed{10}$	$\boxed{44}$	$\boxed{0.07}$	$\boxed{3.1}$
Te Tellurium	69	55	57	60	240	3.8	17
Ti Titanium	310	220	190	$\boxed{200}$	$\boxed{920}$	$\boxed{15}$	$\boxed{65}$
Tl Thallium	35	39	38	40	150	2.4	11
V Vanadium	3.5	3.9	3.8	4.0	15	0.24	1.1
Zn Zinc	$\boxed{450}$	$\boxed{50}$	$\boxed{19}$	$\boxed{6}$	$\boxed{520}$	$\boxed{8.3}$	$\boxed{37}$

All elements except those in boxes ☐ are below the limit of detection

Table VI.1: Summary of Incinerator Stack Source Sampling Tests: Gulf-Strachan Plant: Test #2: Glass Liner

Sample Analyses   Test no 3   Date August 24, 1982

Strachan

Maximum Possible

Sample From	PGM 6a	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight μg	Elemental Concen-tration μg/ref	Elemental Emission Rate gm/hr
Volume (ml)	435	620	216				
Total Particulate (mg)	63	41000	-	14	$E_R = 5.9 \times 10^4$ $E_R = 1.1 \times 10^2$		kg/d (total) kg/d (front end)
Ag Silver	8.7	6.2	6.5	6.0	27	0.36	1.6
Al Aluminum	130	$\boxed{120}$	110	$\boxed{2600}$	$\boxed{3000}$	$\boxed{39}$	$\boxed{180}$
As Arsenic	0.87	$\boxed{1.2}$	0.65	$\boxed{0.96}$	$\boxed{3.7}$	$\boxed{0.05}$	$\boxed{0.22}$
B Boron	1400	1200	1100	1000	4800	63	280
Be Beryllium	3.0	2.5	2.2	1.0	8.7	0.11	0.52
Cd Cadmium	$\boxed{1.4}$	2.5	2.2	2.0	$\boxed{7.7}$	$\boxed{0.10}$	$\boxed{0.46}$
Co Cobalt	30	25	22	20	97	1.3	5.8
Cr Chromium	$\boxed{44}$	25	22	20	$\boxed{110}$	$\boxed{1.5}$	$\boxed{6.5}$
Cu Copper	13	12	11	10	46	0.61	2.7
Fe Iron	$\boxed{380}$	$\boxed{37}$	$\boxed{22}$	$\boxed{40}$	$\boxed{880}$	$\boxed{5.3}$	$\boxed{28}$
Ga Gallium	300	250	220	200	970	13	57
Ge Germanium	300	250	220	200	970	13	57
Hg Mercury	8.7	6.2	6.5	5.0	26	0.35	1.6
In Indium	130	120	110	100	460	6.1	27
Li Lithium	3.0	2.5	2.2	$\boxed{2.0}$	$\boxed{9.7}$	$\boxed{0.13}$	$\boxed{0.58}$
Mn Manganese	8.7	6.2	6.5	6.0	27	0.36	1.6
Mo Molybdenum	$\boxed{87}$	25	22	30	$\boxed{160}$	$\boxed{2.2}$	$\boxed{9.7}$
Ni Nickel	$\boxed{44}$	25	22	20	$\boxed{110}$	$\boxed{1.5}$	$\boxed{6.5}$
Pb Lead	$\boxed{87}$	$\boxed{37}$	22	30	$\boxed{170}$	$\boxed{2.2}$	$\boxed{9.6}$
Sb Antimony	44	50	43	20	160	2.1	9.3
Sc Scandium	87	62	65	40	250	3.3	15
Se Selenium	1.3	1.2	1.1	1.0	4.6	0.06	0.27
Sn Tin	130	120	110	60	420	5.6	25
Sr Strontium	13	12	11	20	56	0.74	3.3
Te Tellurium	87	62	65	60	270	3.6	16
Ti Titanium	300	$\boxed{250}$	220	100	$\boxed{870}$	$\boxed{11}$	$\boxed{52}$
Tl Thallium	44	$\boxed{37}$	43	40	$\boxed{164}$	$\boxed{2.2}$	$\boxed{9.7}$
V Vanadium	4.4	3.7	4.3	4.0	16	0.22	0.97
Zn Zinc	$\boxed{250}$	$\boxed{62}$	$\boxed{30}$	$\boxed{5.6}$	$\boxed{350}$	$\boxed{4.6}$	$\boxed{21}$

All elements except those in boxes ☐ are under the limit of detection

Table VI.2: Summary of Incinerator Stack Source Sampliing Tests: Gulf-Strachan Plant: Test #3· Glass Liner

Sample Analyses   Test No. Prelim   Date August 25, 1982   Ram River

Sample From	PNW	IMP 1	IMP 2,3	IMP 4,5	Filter	Maximum Possible Elemental Weight ug	Elemental Concentration ug/ref	Elemental Emission Rate gm/hr
Volume (ml)	490	470	475	190		$E_R = 3.2 \times 10^4$ kg/d (total)		
Total Particulate (mg)	25	-	4400	-	12	$E_R = 2.6 \times 10^2$ kg/d (front end)		
Ag Silver	29	28	29	11	10	110	1.7	32
Al Aluminum	490	470	480	190	1000	2600	42	780
As Arsenic	0.15	0.14	0.14	0.06	1.0	1.5	0.02	0.44
B Boron	3900	3800	3800	1500	800	14000	220	4100
Be Beryllium	15	19	19	7.6	3.0	63	1.0	19
Cd Cadmium	20	19	19	7.6	4	69	1.1	20
Co Cobalt	98	94	95	38	20	350	5.5	100
Cr Chromium	200	190	190	76	40	690	11	200
Cu Copper	98	94	95	38	20	350	5.5	100
Fe Iron	$\boxed{290}$	190	190	76	40	$\boxed{790}$	$\boxed{13}$	$\boxed{230}$
Ga Gallium	2000	1900	1900	760	400	6900	110	2000
Ge Germanium	2000	1900	1900	760	400	6900	110	2000
Hg Mercury	4.9	4.7	4.8	1.9	20	36	0.58	11
In Indium	2000	1900	1900	760	400	6900	110	2000
Li Lithium	9.8	9.4	9.5	3.8	2.0	35	0.55	10
Mn Manganese	49	47	48	19	10	170	28	51
Mo Molybdenum	490	470	480	190	100	1700	28	510
Ni Nickel	200	190	190	76	40	690	0.18	3.3
Pb Lead	200	190	190	76	40	690	11	200
Sb Antimony	200	190	190	76	40	690	11	200
Sc Scandium	150	140	140	57	30	520	8.3	150
Se Selenium	9.8	9.4	9.5	3.8	2.0	35	0.55	10
Sn Tin	980	940	950	380	100	3400	54	990
Sr Strontium	98	94	95	38	20	350	5.5	100
Te Tellurium	390	380	380	150	80	1400	22	410
Ti Titanium	980	940	950	380	200	3500	55	1000
Tl Thallium	290	280	290	110	60	1000	17	310
V Vanadium	29	28	29	11	4.0	100	1.6	30
Zn Zinc	$\boxed{250}$	$\boxed{38}$	$\boxed{48}$	$\boxed{25}$	$\boxed{880}$	$\boxed{1200}$	$\boxed{20}$	$\boxed{370}$

All elements except those in boxes ☐ are below the limit of detection

Table VI.3: Summary of Incinerator Stack Source Sampling Tests: Canterra-Ram River Plant: Preliminary Survey: Glass Liner

Sample Analyses Test No 1 Date August 26, 1982 Ram River

Sample From	PLW &W	IMP. 1,2,3.	IMP. 4,5	Filter	Total Elemental Weight μg	Maximum Possible Elemental Concentration μg/rcf	Maximum Possible Elemental Emission Rate gm/hr
Volume (ml)	450	950	260	-	$E_R = 2.5 \times 10^5$ kg/d (total)		
Total Particulate (mg)	17	28000	-	37	$E_R = 4.8 \times 10^2$ kg/d (front end)		
Ag Silver	4.5	5.7	5.2	6.0	21	0.41	7.8
Al Aluminum	$\boxed{140}$	$\boxed{95}$	100	$\boxed{5000}$	$\boxed{5300}$	$\boxed{100}$	$\boxed{2000}$
As Arsenic	0.45	0.57	0.52	$\boxed{1.6}$	$\boxed{3.1}$	$\boxed{0.06}$	$\boxed{1.1}$
B Boron	1300	1100	1000	1000	4500	85	1600
Be Beryllium	2.7	1.9	2.1	1.0	7.7	0.15	2.8
Cd Cadmium	$\boxed{4.5}$	1.9	2.1	2.0	$\boxed{11}$	$\boxed{0.20}$	$\boxed{3.8}$
Co Cobalt	27	19	21	20	87	1.6	32
Cr Chromium	27	19	21	20	87	1.6	32
Cu Copper	14	9.5	10	10	43	0.82	16
Fe Iron	$\boxed{63}$	$\boxed{56}$	$\boxed{42}$	$\boxed{130}$	$\boxed{290}$	$\boxed{5.5}$	$\boxed{110}$
Ga Gallium	270	190	210	200	870	16	320
Ge Germanium	270	190	210	200	870	16	320
Hg Mercury	9.0	4.8	5.2	5.0	24	0.45	8.8
In Indium	140	95	100	100	430	8.2	160
Li Lithium	2.7	1.9	2.1	$\boxed{2.0}$	$\boxed{8.7}$	$\boxed{0.17}$	$\boxed{3.2}$
Mn Manganese	4.5	5.7	5.2	6.0	22	0.41	7.8
Mo Molybdenum	27	19	21	$\boxed{20}$	$\boxed{87}$	$\boxed{1.6}$	$\boxed{32}$
Ni Nickel	27	19	21	20	87	1.6	32
Pb Lead	27	$\boxed{38}$	21	20	$\boxed{110}$	$\boxed{2.0}$	$\boxed{39}$
Sb Antimony	45	48	52	20	160	3.1	60
Sc Scandium	90	67	52	40	250	4.7	91
Se Selenium	1.4	0.95	1.0	1.0	4.3	0.08	1.6
Sn Tin	140	$\boxed{230}$	100	60	$\boxed{530}$	$\boxed{10}$	$\boxed{190}$
Sr Strontium	$\boxed{27}$	$\boxed{9.5}$	$\boxed{10}$	$\boxed{20}$	$\boxed{67}$	$\boxed{1.3}$	$\boxed{24}$
Te Tellurium	45	57	52	60	210	4.1	78
Ti Titanium	270	190	210	$\boxed{200}$	$\boxed{870}$	$\boxed{16}$	$\boxed{320}$
Tl Thallium	41	38	26	40	140	2.7	53
V Vanadium	4.1	3.8	2.6	4.0	14	0.27	5.3
Zn Zinc	$\boxed{39}$	$\boxed{72}$	$\boxed{31}$	$\boxed{16}$	$\boxed{160}$	$\boxed{3.0}$	$\boxed{58}$

All elements except those in boxes ☐ are below the limit of detection

Table VI.4: Summary of Incinerator Stack Source Sampling Tests: Canterra-Ram River Plant: Test #1: Glass Liner

Sample Analyses Test No 3 Date August 28, 1982

Ram River

Sample From	PCN 6W	IMP. 1,2,3.	IMP. 4,5	Filter	Total Elemental Weight µg	Maximum Possible Elemental Concentration µg/ref	Maximum Possible Elemental Emission Rate gm/hr
Volume (ml)	600	925	215		$E_R = 2.1 \times 10^5$		kg/d (total)
Total Particulate (mg)	49	32000	32	-	$E_R = 5.3 \times 10^2$		kg/d (front end)
Ag Silver	6.0	5.6	6.5	6.0	24	0.35	6.5
Al Aluminum	$\boxed{120}$	93	110	$\boxed{10000}$	$\boxed{10000}$	$\boxed{150}$	$\boxed{2800}$
As Arsenic	0.60	0.56	0.65	1.1	2.9	0.04	0.79
B Boron	1200	1200	1100	1000	4500	65	1200
Be Beryllium	2.4	2.8	2.2	1.0	8.3	0.12	2.3
Cd Cadmium	$\boxed{3.6}$	2.8	2.2	2.0	$\boxed{11}$	$\boxed{0.15}$	$\boxed{2.9}$
Co Cobalt	24	28	22	20	93	1.3	25
Cr Chromium	$\boxed{60}$	28	22	20	$\boxed{130}$	$\boxed{1.9}$	$\boxed{35}$
Cu Copper	$\boxed{24}$	9.3	11	10	$\boxed{54}$	$\boxed{0.78}$	$\boxed{15}$
Fe Iron	$\boxed{320}$	$\boxed{35}$	$\boxed{32}$	$\boxed{100}$	$\boxed{490}$	$\boxed{7.1}$	$\boxed{130}$
Ga Gallium	240	280	220	200	930	13	250
Ge Germanium	240	280	220	200	930	13	250
Hg Mercury	6.0	4.6	6.5	5.0	22	0.32	6.0
In Indium	120	93	110	100	420	6.1	110
Li Lithium	2.4	2.8	2.2	$\boxed{4.0}$	$\boxed{11}$	$\boxed{0.16}$	$\boxed{3.1}$
Mn Manganese	$\boxed{7.2}$	5.6	6.5	6.0	$\boxed{25}$	$\boxed{0.37}$	$\boxed{6.9}$
Mo Molybdenum	24	28	22	20	93	1.3	26
Ni Nickel	36	28	22	20	110	1.5	29
Pb Lead	24	28	22	20	93	1.3	25
Sb Antimony	48	46	43	20	160	2.3	43
Sc Scandium	60	74	65	40	240	3.5	65
Se Selenium	1.2	0.93	1.1	1.0	4.2	0.06	1.1
Sn Tin	120	93	110	60	380	5.5	110
Sr Strontium	$\boxed{12}$	$\boxed{9.3}$	11	$\boxed{20}$	$\boxed{52}$	$\boxed{0.75}$	$\boxed{14}$
Te Tellurium	60	56	65	60	240	3.5	66
Ti Titanium	240	280	220	$\boxed{200}$	$\boxed{930}$	$\boxed{13}$	$\boxed{250}$
Tl Thallium	36	37	43	40	160	2.3	43
V Vanadium	3.6	3.7	4.3	4.0	16	0.23	4.3
Zn Zinc	$\boxed{37}$	$\boxed{41}$	$\boxed{20}$	$\boxed{22}$	$\boxed{120}$	$\boxed{1.7}$	$\boxed{33}$

All elements except those in boxes ☐ are below the limit of detection

Table VI.5: Summary of Incinerator Stack Source Sampling Tests: Canterra-Ram River Plant: Test #3: Glass Liner

Test No Prelim   Date August 30/1982   Jumping Pound

Sample Analyses Sample From	P&W &W	IMP. 1,2,3.	IMP. 4,5	Filter	Total Elemental Weight µg	Maximum Possible Elemental Concen-tration µg/scf	Elemental Emission Rate gm/hr
Volume (ml)	605	885	160		E_R = 9.4 x 10^4	kg/d (total)	
Total Particulate (mg)	85	37000	-	45	E_R = 3.3 x 10^2	kg/d (front end)	
Ag Silver	6.1	6.2	8.0	6.0	26	0.74	2.8
Al Aluminum	$\boxed{240}$	$\boxed{89}$	160	$\boxed{100}$	$\boxed{590}$	$\boxed{17}$	$\boxed{63}$
As Arsenic	$\boxed{[illegible]}$	$\boxed{2.7}$	1.6	5.0	$\boxed{14}$	$\boxed{0.40}$	$\boxed{1.5}$
B Boron	1200	890	1600	1000	4700	130	500
Be Beryllium	2.4	2.7	3.2	1.0	9.3	0.26	0.98
Cd Cadmium	$\boxed{350}$	2.7	3.2	2.0	$\boxed{360}$	$\boxed{10}$	$\boxed{38}$
Co Cobalt	24	27	32	10	93	2.6	9.8
Cr Chromium	$\boxed{61}$	$\boxed{27}$	32	20	$\boxed{140}$	$\boxed{3.9}$	$\boxed{15}$
Cu Copper	$\boxed{48}$	$\boxed{[illegible]}$	16.0	10	$\boxed{83}$	$\boxed{2.4}$	$\boxed{8.8}$
Fe Iron	$\boxed{1900}$	$\boxed{89}$	$\boxed{32}$	$\boxed{60}$	$\boxed{2000}$	$\boxed{60}$	$\boxed{220}$
Ga Gallium	240	270	320	200	1000	29	110
Ge Germanium	120	89	160	100	470	13	47
Hg Mercury	1.2	0.89	1.6	1.0	4.7	0.13	0.50
In Indium	120	89	160	100	470	13	50
Li Lithium	1.2	0.89	1.6	0.60	4.3	0.12	0.46
Mn Manganese	$\boxed{56}$	6.2	8.0	6.0	$\boxed{75}$	$\boxed{2.1}$	$\boxed{7.9}$
Mo Molybdenum	61	62	80	50	250	7.2	27
Ni Nickel	$\boxed{270}$	27	32	20	$\boxed{340}$	$\boxed{9.8}$	$\boxed{37}$
Pb Lead	$\boxed{910}$	27	32	20	$\boxed{990}$	$\boxed{28}$	$\boxed{100}$
Sb Antimony	48	53	64	20	190	5.3	20
Sc Scandium	61	62	80	20	220	6.3	24
Se Selenium	1.2	0.89	1.6	1.0	4.7	0.13	0.50
Sn Tin	120	89	160	50	420	12	45
Sr Strontium	6.1	6.2	8.0	5.0	25	0.71	2.7
Te Tellurium	61	62	80	60	260	7.4	28
Ti Titanium	$\boxed{240}$	$\boxed{89}$	160	60	$\boxed{550}$	$\boxed{16}$	$\boxed{58}$
Tl Thallium	61	62	80	50	250	7.2	27
V Vanadium	2.4	2.7	3.2	2.0	10	0.29	1.1
Zn Zinc	$\boxed{150}$	$\boxed{62}$	4.8	$\boxed{48}$	$\boxed{260}$	$\boxed{7.4}$	$\boxed{28}$

All elements except those in boxes ☐ are below the limit of detection

Table VI.6: Summary of Incinerator Stack Source Sampling Tests: Shell-Jumping Pound: Preliminary Survey: Glass Liner

Sample Analyses Test no 2 Date September 1/82 . JUMPING POUND

Sample From	P&W 6M	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight μg	Maximum Possible Elemental Concentration μg/scf	Maximum Possible Elemental Emission Rate gm/hr
Volume (ml)	560	830	330		$E_R = 6.3 \times 10^4$		kg/d (total)
Total Particulate (mg)	52	40000	-	8.1	$E_R = 9.5 \times 10^1$		kg/d (front end)
Ag Silver	5.6	5.8	6.6	6.0	24	0.41	1.6
Al Aluminum	$\boxed{170}$	$\boxed{83}$	$\boxed{99}$	$\boxed{100}$	$\boxed{450}$	$\boxed{7.6}$	$\boxed{30}$
As Arsenic	1.7	0.83	0.99	5.0	8.5	0.14	0.56
B Boron	1700	830	990	1000	4500	76	300
Be Beryllium	2.8	2.5	2.3	1.0	8.6	0.15	0.57
Cd Cadmium	$\boxed{4.5}$	2.5	2.3	2.0	$\boxed{11}$	$\boxed{0.19}$	$\boxed{0.74}$
Co Cobalt	28	25	23	10	86	1.5	5.7
Cr Chromium	28	25	23	20	96	1.6	6.3
Cu Copper	$\boxed{28}$	6.3	9.9	$\boxed{80}$	$\boxed{110}$	$\boxed{1.8}$	$\boxed{7.0}$
Fe Iron	$\boxed{500}$	$\boxed{50}$	$\boxed{33}$	$\boxed{20}$	$\boxed{610}$	$\boxed{10}$	$\boxed{40}$
Ga Gallium	280	250	230	200	960	16	63
Ge Germanium	170	83	99	100	450	7.6	30
Hg Mercury	1.7	0.83	0.99	1.0	4.5	0.08	0.30
In Indium	170	83	99	100	450	7.6	30
Li Lithium	1.7	0.83	0.99	0.6	4.1	0.07	0.27
Mn Manganese	$\boxed{39}$	5.8	6.6	6.0	$\boxed{58}$	$\boxed{0.98}$	$\boxed{3.8}$
Mo Molybdenum	56	58	66	50	230	3.9	15
Ni Nickel	$\boxed{45}$	25	23	20	$\boxed{110}$	$\boxed{1.9}$	$\boxed{7.4}$
Pb Lead	$\boxed{28}$	25	23	20	$\boxed{96}$	$\boxed{1.6}$	$\boxed{6.3}$
Sb Antimony	56	50	33	20	160	2.7	10
Sc Scandium	56	58	66	20	200	3.4	13
Se Selenium	1.7	0.83	0.99	1.0	4.5	0.08	0.30
Sn Tin	170	83	99	50	400	6.8	26
Sr Strontium	5.6	5.8	6.6	$\boxed{9.0}$	$\boxed{27}$	$\boxed{0.46}$	$\boxed{1.8}$
Te Tellurium	56	58	66	60	240	4.1	16
Ti Titanium	170	$\boxed{250}$	$\boxed{230}$	60	$\boxed{710}$	$\boxed{12}$	$\boxed{47}$
Tl Thallium	56	58	66	$\boxed{50}$	$\boxed{230}$	$\boxed{3.9}$	$\boxed{15}$
V Vanadium	4.5	2.5	2.3	2.0	11	0.19	0.74
Zn Zinc	$\boxed{130}$	$\boxed{25}$	$\boxed{26}$	$\boxed{88}$	$\boxed{270}$	$\boxed{4.6}$	$\boxed{18}$

All elements except those in boxes ☐ are below the limit of detection

Table VI.7: Summary of Incinerator Stack Source Sampling Tests: Shell-Jumping Pound Test #2: Glass Liner

Sample Analyses Test No 3 Date September 2/1982 Jumping Pound

Sample From	P&M 6m	IMP. 1,2,3,	IMP. 4,5	Filter	Maximum Possible Total Elemental Weight μg	Elemental Concentration μg/ref	Elemental Emission Rate gm/hr
Volume (ml)	420	930	360		$E_R = 6.9 \times 10^4$		kg/d (total)
Total Particulate (mg)	78	57000	-	8.8	$E_R = 1.9 \times 10^2$		kg/d (front end)
Ag Silver	8.4	5.6	3.6	6.0	24	0.31	1.2
Al Aluminum	130	93	110	$\boxed{200}$	$\boxed{530}$	$\boxed{6.9}$	$\boxed{27}$
As Arsenic	1.3	0.93	1.1	5.0	8.3	0.11	0.42
B Boron	1300	930	1100	1000	4300	56	220
Be Beryllium	2.9	2.8	2.5	1.0	9.3	0.12	0.47
Cd Cadmium	$\boxed{4.2}$	2.8	2.5	2.0	$\boxed{12}$	$\boxed{0.15}$	$\boxed{0.58}$
Co Cobalt	290	27	25	10	360	4.7	18
Cr Chromium	$\boxed{42}$	28	25	20	$\boxed{120}$	$\boxed{1.5}$	$\boxed{5.8}$
Cu Copper	$\boxed{42}$	9.3	11	10	$\boxed{72}$	$\boxed{0.95}$	$\boxed{3.7}$
Fe Iron	$\boxed{840}$	$\boxed{74}$	$\boxed{11}$	10	$\boxed{940}$	$\boxed{12}$	$\boxed{47}$
Ga Gallium	290	280	250	200	1000	13	52
Ge Germanium	130	93	110	100	430	5.6	22
Hg Mercury	1.3	0.93	1.1	1.0	4.3	0.06	0.22
In Indium	130	93	110	100	430	5.6	22
Li Lithium	1.3	0.93	1.1	0.6	3.9	0.05	0.20
Mn Manganese	$\boxed{42}$	5.6	7.2	6.0	$\boxed{61}$	$\boxed{0.80}$	$\boxed{3.1}$
Mo Molybdenum	84	56	72	50	260	3.4	13
Ni Nickel	$\boxed{84}$	28	25	20	$\boxed{160}$	$\boxed{2.1}$	$\boxed{8.0}$
Pb Lead	29	28	36	20	100	1.3	5.2
Sb Antimony	42	47	36	$\boxed{60}$	$\boxed{180}$	$\boxed{2.4}$	$\boxed{9.3}$
Sc Scandium	84	56	72	20	230	3.0	12
Se Selenium	1.3	0.93	1.1	1.0	4.3	0.06	0.22
Sn Tin	130	$\boxed{280}$	110	50	$\boxed{560}$	$\boxed{7.4}$	$\boxed{28}$
Sr Strontium	8.4	5.6	7.2	$\boxed{6.0}$	$\boxed{27}$	$\boxed{0.36}$	$\boxed{1.4}$
Te Tellurium	84	56	72	60	270	3.6	14
Ti Titanium	130	280	110	60	570	7.5	29
Tl Thallium	84	56	72	50	260	3.4	13
V Vanadium	2.9	2.8	2.5	2.0	10	0.13	0.52
Zn Zinc	$\boxed{410}$	$\boxed{9.1}$	$\boxed{22}$	$\boxed{22}$	$\boxed{460}$	$\boxed{6.0}$	$\boxed{23}$

All elements except thoses in boxes ☐ are below the limit of detection

VI.8: Summary of Incinerator Stack Source Sampling Tests: Shell-Jumping Pound Test #3: Glass Liner

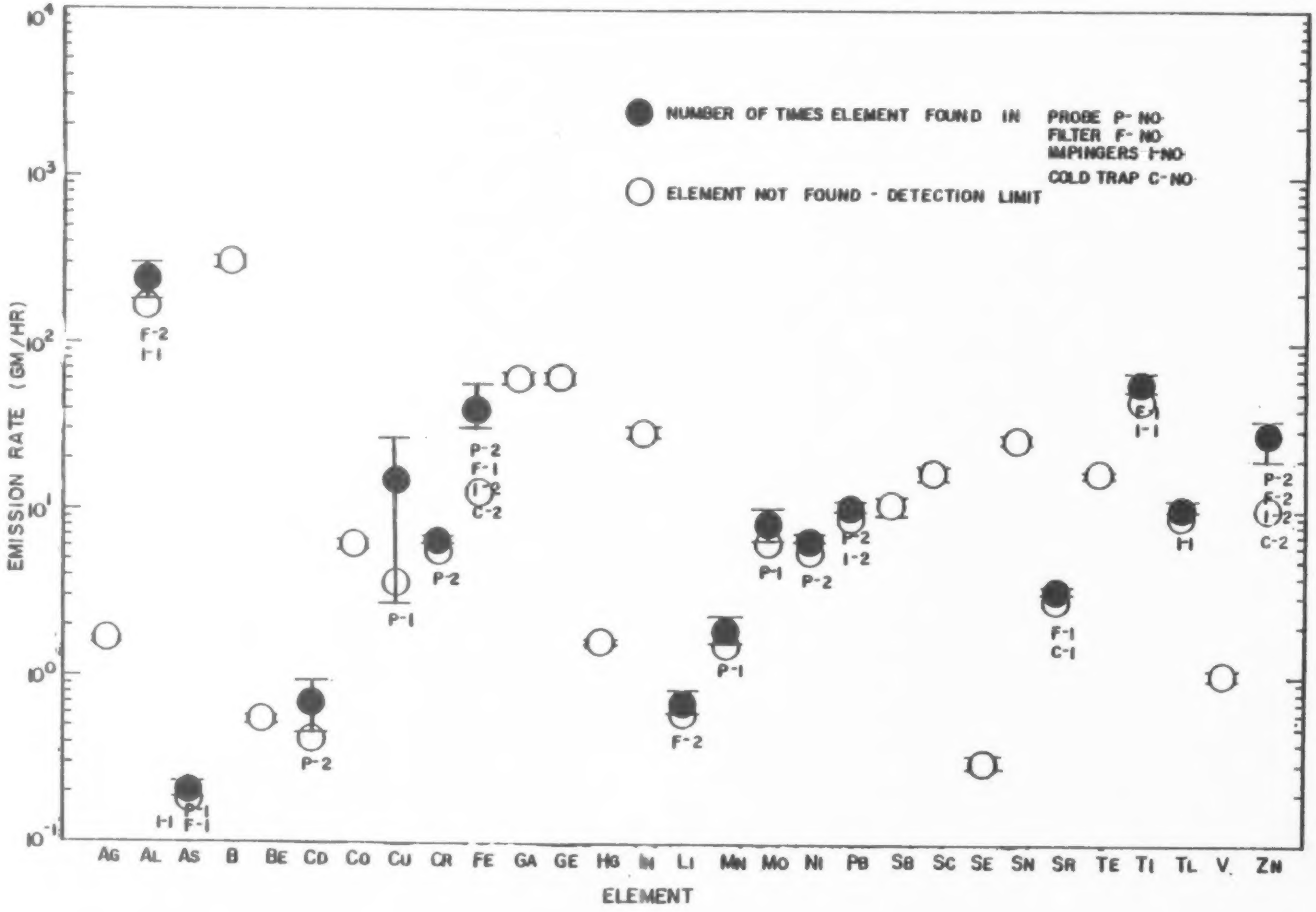


Figure VI.1: Maximum Possible Emission Rates of All Elements in Gulf-Strachan Incinerator Stack Gases (Glass Liner)

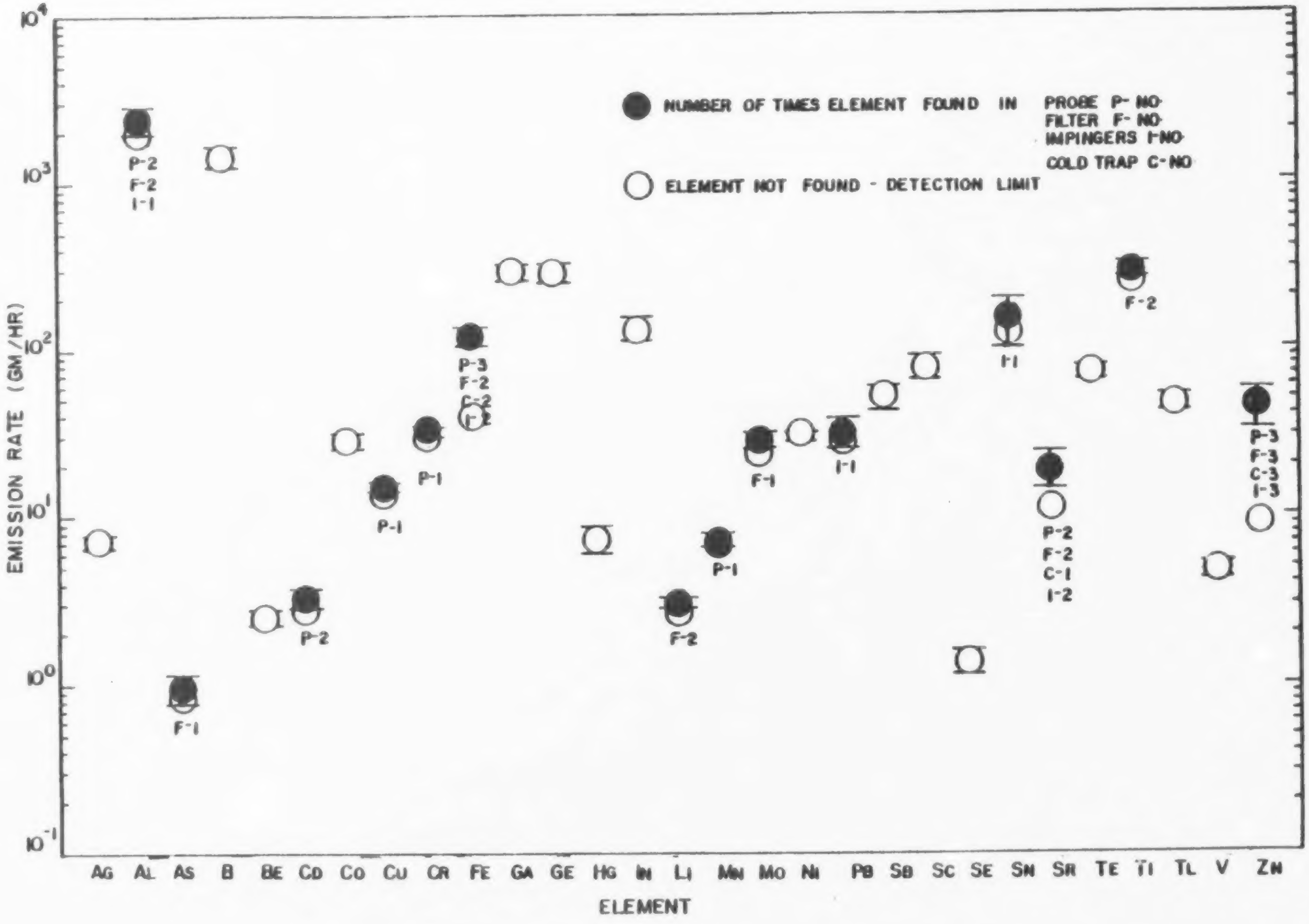


Figure VI.2: Maximum Possible Emission Rates of All Elements in Canterra-Ram River Incinerator Stack Gases (Glass Liner)

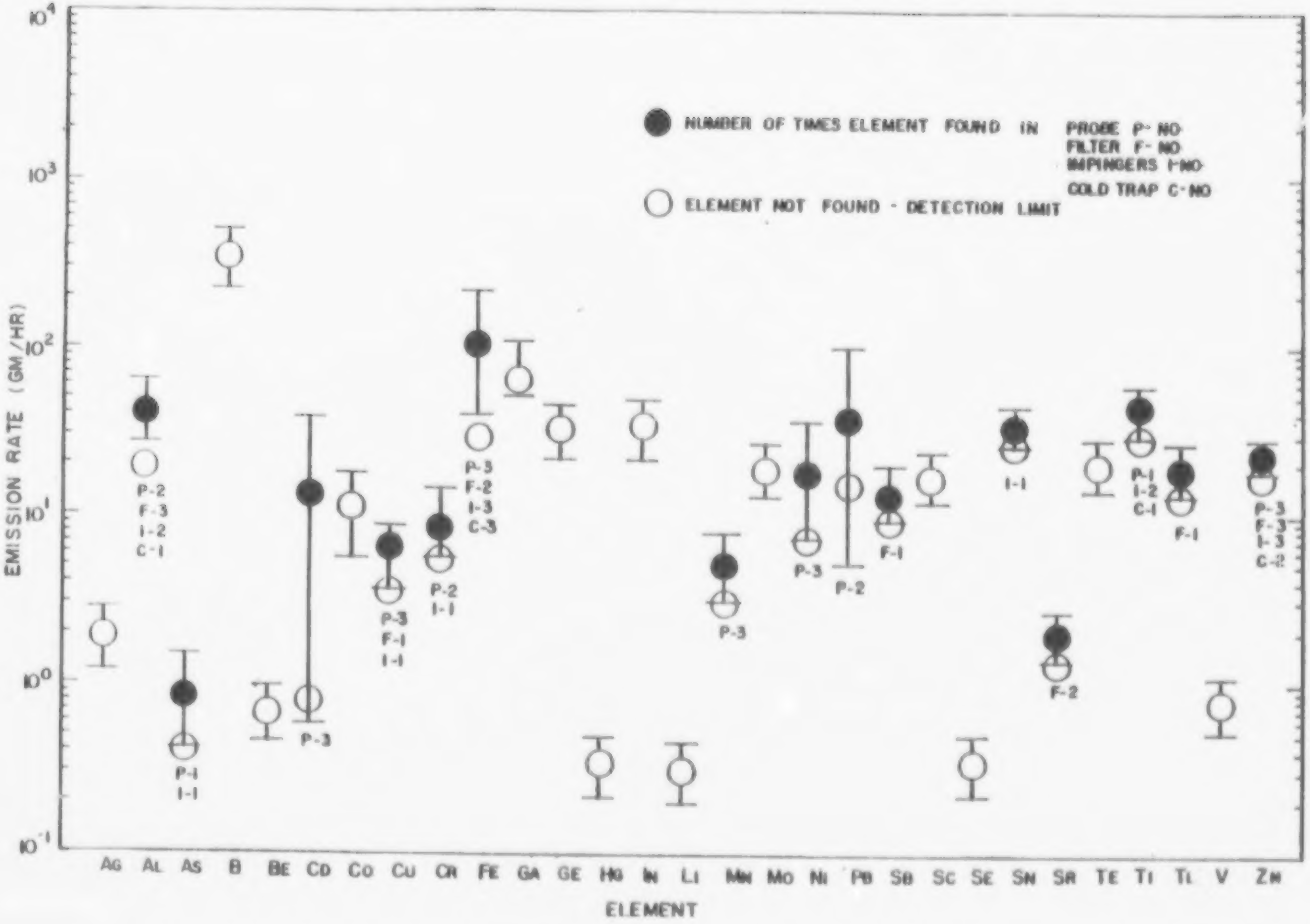


Figure VI.3: Maximum Possible Emission Rates of All Elements in Shell-Jumping Pound Incinerator Stack Gases (Glass Liner)

Test	Mass of Strontium Collected (ug)					Maximum Possible Strontium Stack Gas		Comments
	Probe & Nozzle (Washes)	Impingers 1,2,3	Impingers 4,5	Filter	Total Sampling Train	Concentration (ug/rcf)	Emission Rate (g/hr)	
Preliminary	6.1	6.2	8.0	5.0	25.3	0.71	2.7	No detection: only LOD levels reported
#2	5.6	5.8	6.6	$\boxed{9.0}$	$\boxed{27.0}$	$\boxed{0.46}$	$\boxed{1.8}$	Strontium detected on filter: emission rate based on measured and LOD values
#3	8.4	5.6	7.2	$\boxed{6.0}$	$\boxed{27.2}$	$\boxed{0.36}$	$\boxed{1.4}$	Strontium detected on filter: emission rate based on measured and LOD values

☐ Element positively detected

Table V1.9 Summary of Strontium Determinations at the Shell-Jumping Pound Gas Plant (Borosilicate Glass Liner).

A comparison of the masses of strontium collected in different parts of the sampling train and resultant evaluations of stack gas concentrations and emission rates for the Preliminary Survey and Test #2 shows that although the presence of strontium was never "detected" during the Preliminary Survey, the respective magnitudes are, with the exception of the filter catch, generally higher that those corresponding to Test #2. Although the Test #2 emission rate (1.8 g/h) is lower than the 2.7 g/h value calculated for the Preliminary Survey, it is reported as exceeding the limit of detection for that test. On the other hand, the Preliminary Survey rate is considered as the maximum value that could be expected if strontium was present in the stack gases at levels resulting in ultimate resolution concentrations equal to the Limit of Detection for instrumental assessment.

Since the presence of strontium was "detected" in Tests #2 and #3, the number of "detections" satisfy the criteria for "establishment" of the presence of strontium in the Shell-Jumping Pound Gas Plant Incinerator Stack gases. As a result, strontium would be included in Table 5.14.

The apparent contradiction created by lower emission rates being reported as measured values while higher ones are considered to be hypothetical upper limits can be resolved by reference to Figure VI.4. This schematic illustrates the evaluation of the emission rate of some arbitrary element "X" for which the instrumental limit of detection (LOD) value is assumed to be 1 ug/L.

Steps #1 and #2 involve analysis of aliquots of different volumes of field solutions (A = 400 mL vs. B = 600 mL) which captured element "X" from different volumes of stack gases (100 m^3 vs. 150 m^3). Since the concentrations of both aliquots are below the instrumental limit of detection for element "X", they must be reported as being less than 1 ug/L. On this basis, both samples overestimate the true emission rate considerably.

Concentration of the field liquids (A and B) to 100 mL before analysis according to Steps #3 and #4, provides one solution (C) for which the concentration will be reported as being less than 1 ug/L. The resultant emission rate of 1 ug/s is still an overestimate of the true value. It would be reported as a maximum possible emission rate. However, ultimate solution (D) provides a measurable concentration from which the true emission rate can be evaluated as 0.8 ug/s.

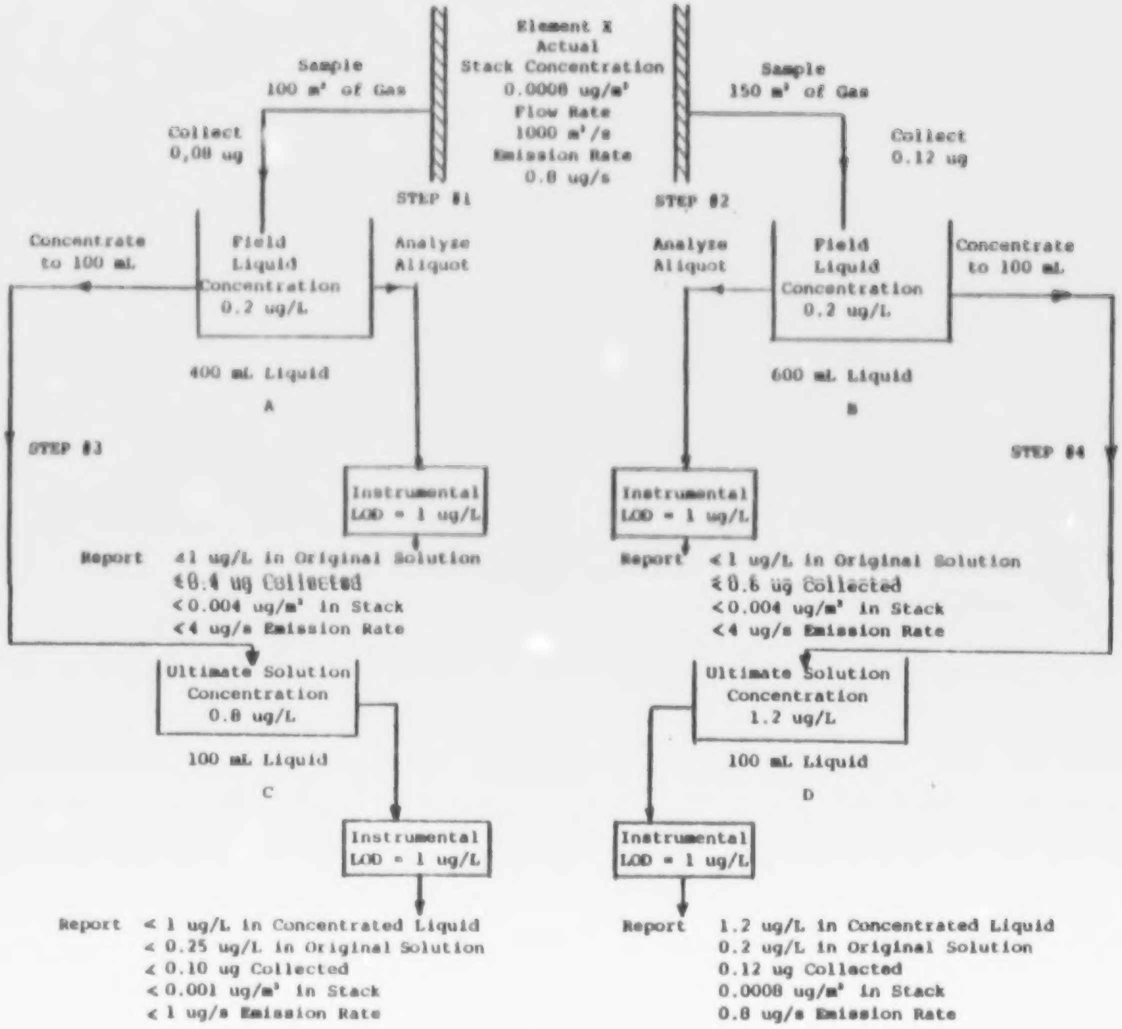


Figure V1.4 Effect of Preconcentration on Reported Emission Rates